UNITED STATES ARMY IN WORLD WAR II

The Technical Services

THE CHEMICAL WARFARE SERVICE: FROM LABORATORY TO FIELD

by

Leo P. Brophy, Wyndham D. Miles

and

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CENTER OF MILITARY HISTORY

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UNITED STATES ARMY IN WORLD WAR II

Stetson Conn, General Editor

History of

THE CHEMICAL WARFARE SERVICE

Organizing for War

From Laboratory to Field

Chemicals in Combat

. . . to Those Who Served

Foreword

Rather belatedly, the United States Army in preparing for World War II investigated on an intensive and very large scale the chemical munitions that might be necessary or useful in fighting the Axis powers. This effort required the collaboration of a host of civilian scientists and research centers as well as a great expansion of the laboratories and proving grounds of the Chemical Warfare Service itself. A similar development, recounted at the beginning of this work, came too late to influence the outcome of World War I. In World War II, on the other hand, the Army not only prepared against gas warfare sufficiently well to discourage its employment by the enemy, but also developed a number of new chemical weapons that contributed materially to victory. The authors add perspective and interest to their story by telling very briefly about corresponding German and Japanese activity.

The manufacture of chemical munitions in quantity was possible only through a rapid expansion of private industry to support and supplement the work of Army arsenals. Both necessity and choice led the Chemical Warfare Service to make widespread use of small industrial concerns throughout the United States, and the account of production in this work is especially pertinent to a consideration of the problems involved in military contracting with small business on a big scale. In this and other respects, *From Laboratory to Field* complements other volumes in the Army series dealing with problems of military procurement. Readers generally as well as members of the Chemical Corps particularly should find it instructive.

Washington, D.C.
9 June 1959

WARREN H. HOOVER
Colonel, U.S.A.
Acting Chief of Military History

The Authors

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Preface

This volume, the second in a series of three devoted to the Chemical Warfare Service (CWS) in World War II, now the Chemical Corps, covers research, development, procurement, and distribution of chemical warfare matériel. It traces the history of these activities from the World War I period, when the CWS was activated to supervise the offensive and defensive aspects of gas warfare throughout the Army, until the end of World War II. The first volume in the series, *Organizing for War,* discusses the development of the CWS organization and mission as well as personnel management and military training. The third volume, entitled *Chemicals in Combat,* will deal with chemical warfare activities in the theaters of operations.

In treating research and development, the present volume concentrates on CWS projects that proved of greatest significance to the armed forces during World War II. It attempts to point up the problems that arose in the course of research and development and to indicate the solutions which the scientists hit upon. Since research and development in the zone of the interior was closely related to research and development in the theaters of operations, the volume covers activities in both areas.

In contrast to research and development, procurement and distribution differed considerably as between the zone of the interior and the theaters of operations; in the theaters these activities were closely associated with the commanders' combat responsibilities. The volume, therefore, confines itself to a review of procurement and distribution in the zone of the interior, leaving narration of theater activities to the forthcoming *Chemicals in Combat.*

In World War II the CWS procured a variety of munitions and components both from government arsenals and from private industry. For some of these items the service had prepared plans in the prewar years, but for others it had not had the opportunity to make such plans.

Procurement by the CWS of some items was on a scale never before experienced in peace or war. As in the treatment of research and development, the volume attempts to devote major attention to items that proved significant to the war effort.

Dr. Leo P. Brophy wrote all of the chapters and sections of chapters dealing with procurement and distribution. He was assisted in the research and writing of Chapters XIV and XVI by Mr. Sherman L. Davis of the Historical Staff, Chemical Corps. Dr. Wyndham D. Miles wrote all of the chapters on research and development except the section of Chapter IV dealing with the treatment of gas casualties and Chapter V. The latter were researched and put in draft form by Dr. Rexmond C. Cochrane. Dr. Brooks E. Kleber and Mr. Dale Birdsell reviewed the chapters and offered helpful comments.

The authors of this volume were greatly aided in their research by the competent staff of the National Archives, particularly Mr. Robert W. Krauskopf of Modern Army Branch and Mrs. Caroline Moore, Mrs. Lois C. Aldridge, and Mrs. Hazel Ward of the World War II Records Division, National Archives and Records Service; Mr. Charles E. McCusker, Mr. Howard V. Baute, Mrs. M. Virginia Nester, and Mrs. Mary K. Stuart of the Federal Records Center, GSA, Alexandria, Va.; Mr. Joseph A. Logan, Office of the Comptroller of the Army; Miss Clara J. Widger, Librarian, Industrial College of Armed Forces; and Mr. Robert T. Baldwin of the Chlorine Institute, New York City. Members of the U.S. Army Chemical Corps records and technical information staff, particularly Miss Alice M. Amoss, U.S. Army Chemical Corps Chemical Warfare Laboratories, Mrs. Marion O. Varney, Miss Ethel M. Owens and the late Mrs. Elizabeth V. Owens of the Office of the Chief Chemical Officer, were most helpful. Mrs. Alice E. Moss assisted in the verification of sources and supervised the typing of the manuscript.

The authors are indebted to the many veterans of the Chemical Warfare Service who through interviews and otherwise aided them in writing the volume. Special thanks are due for the assistance afforded by Maj. Gen. Charles E. Loucks, Brig. Gen. Clifford L. Sayre, Brig. Gen. Harold Walmsley, Col. Philip J. FitzGerald, Mr. Marvin J. Silberman, Mr. Robert M. Estes, Dr. L. Wilson Greene, Lt. Col. Allan C. Hamilton, Col. W. P. Fuller Brawner, Col. Frank M. Arthur, Mr. Lester J. Conkling, Col. Ralph W. Hufferd, and Mr. Roman L. Ortynsky.

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Washington, D.C.
15 June 1959

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All illustrations are from Department of Defense files.

THE CHEMICAL WARFARE SERVICE: FROM LABORATORY TO FIELD

CHAPTER I

Research and Supply in World War I

Although armies have used crude chemical devices since ancient times, chemical warfare, as an applied science, is comparatively modern.[1] Chemical warfare came along as a companion of modern chemistry, which itself dates from the late 1700's, when natural philosophers brought about a revolution in this science. As a result of this pioneer work, chemists uncovered a multitude of facts and conceived laws to hold these facts together. By the middle of the 19th century it was a simple matter for men with a knowledge of chemistry to visualize the application of toxic chemicals to warfare, and to suggest specific methods of using them.

During the Crimean War the British chemist Lyon Playfair proposed that a naval shell containing cacodyl cyanide, a toxic organic arsenic compound, be fired into Russian ships.[2] In the same war Admiral Thomas Cochrane urged that an attempt be made to drive the Russians out of Sevastopol by burning huge quantities of sulphur in front of the fortress and letting the wind carry sulphur dioxide gas into enemy positions.[3] In the American Civil War, John W. Doughty of New York sent plans for a chlorine filled shell to the War Department, and Forrest Shepherd of New Haven recommended to President Lincoln that a cloud of hydrogen

[1] Examples of the primitive use of chemicals may be found in: (1) Charles Hederer and Mark Istin, *L'Arme Chimique et Ses Blessures* (Paris: J. B. Bailliere, 1935), pp. 18–25. (2) Rudolf Hanslian, ed., *Der Chemische Krieg* (Berlin: E. S. Mittler & Sohn, 1937), I, 1–4. (3) Julius Meyer, *Der Gaskampf und die Chemischen Kampfstoffe* (3d ed, Leipzig: S. Hirzel, 1938), pp. 12–23. (4) Tenney L. Davis and James R. Ware, "Early Chinese Military Pyrotechnics," *Journal of Chemical Education*, 24 (1947), 522–37.

[2] Wemyss Reid, *Memoirs and Correspondence of Lyon Playfair* (New York and London: Harper & Brothers, 1899), pp. 159–60.

[3] Wyndham D. Miles, "Admiral Cochrane's Plans for Chemical Warfare." *Armed Forces Chemical Journal*, XI (November–December 1957), 22–23.

chloride be used to drive the Confederates out of Petersburg.[4] During the century several other men proposed the use of toxic chemicals in munitions.[5]

Despite arguments that the use of chemicals in warfare was practical and that chemicals would cause less suffering than conventional weapons, national governments refused to test the ideas. Finally in 1915 Fritz Haber convinced the German Army that chlorine could force the Allies out of the trenches and he was given the responsibility of emplacing cylinders of gas in the front lines near Ypres. The first gas cloud attack, launched on a favorable breeze in the afternoon of 22 April, was a success.[6] Allied troops were driven from their positions and only the failure of the German Army to exploit this advantage saved the Allies from a more serious setback.

Once the practicality of chemical warfare had been demonstrated the belligerents organized special units to employ military chemicals, and to conduct chemical and medical research. In the United States the War Department gave responsibility for designing protective equipment to the Medical Department in late 1915, but the Army did not set up combat chemical units or begin scientific investigations until mid-1917.[7]

The Committee on Noxious Gases, National Research Council

The first American chemical warfare research was not carried out by the Army, but by the Bureau of Mines. Early in 1917, as the strained relations between the United States and Germany approached the breaking point, the Secretary of the Interior requested the bureaus in his Department to determine how they could assist the government if the country were drawn into the war. On 7 February Van H. Manning, Director of the Bureau of Mines, called together his division chiefs to discuss the question. During the meeting George S. Rice suggested that the bureau might turn its experience in mine gases and rescue apparatus toward the

[4] Wyndham D. Miles, "Chemical Warfare in the Civil War," *ibid.*, XII (March–April 1958), 26–27, 33.

[5] (1) Brig. Gen. Amos A. Fries and Maj. Clarence J. West, *Chemical Warfare* (New York: McGraw-Hill, 1921), pp. 4–9. (2) Hanslian, *Der Chemische Krieg*, pp. 4–8 (3) Meyer, *Der Gaskampf*, pp. 23–28.

[6] The chlorine attack at Ypres has been discussed by many writers. See especially: Rudolf Hanslian, *Der Deutsche Gasangriff bei Ypern am 22 April 1915* (Berlin: Verlag Gasschutz and Luftschutz, 1934).

[7] "The Medical Department of the United States in the World War," vol. XIV, *Medical Aspects of Gas Warfare* (Washington, 1926), p. 27.

investigation of war gases and masks.[8] The following day Manning notified the Military Committee of the National Research Council that the bureau stood ready to assist the Army and Navy on any problems that might arise in the development of masks.[9] Through the months of February and March the NRC considered the matter. The bureau, in the meantime, did not remain inactive but laid plans for research. On 3 April, with the declaration of war imminent, the council accepted the bureau's offer of co-operation, and appended to the Military Committee a Subcommittee on Noxious Gases composed of Army and Navy officers, members of the NRC's Chemistry Committee, and the Director of the Bureau of Mines (chairman), "to carry on investigations into noxious gases, generation, and antidote for same, for war purposes; also investigations into gas masks." [10]

During the early days of its existence, the Subcommittee on Noxious Gases was extremely important in initiating and co-ordinating chemical warfare research. It met frequently to discuss information received from abroad, and upon request it gave advice to the Army and Navy on questions regarding chemical warfare. Its most important act, however, was to approve a plan of research for the Bureau of Mines. It is clear from the records that the directing force here was Manning and a small but extremely enthusiastic group of men whom he brought together to act as the nucleus of a chemical warfare research organization. Manning and his staff drew up a detailed plan for research, based on reports of the state of chemical warfare in Europe, and then laid the plan before the subcommittee. After some discussion the group approved the plan, thus enabling Manning to proceed.[11] It was from this action by the NRC Subcommittee on Noxious Gases that the Bureau of Mines derived the authority, which it exercised for more than a year, to carry on chemical warfare research and development projects for the Army and Navy. The Subcommittee on

[8] Memo by George S. Rice, Bureau of Mines, regarding early history of mask and gas investigations for the army, 9 Jan 18. War Gas Investigations, Records of Bureau of Mines (National Archives). Cited hereafter as War Gas Investigations, Bu of Mines.

[9] Van H. Manning, *War Gas Investigations*, Bu of Mines Bull 178–A (Washington, 1919).

[10] Meeting of the Military Committee of the NRC, 3 Apr 17. War Gas Investigations, Bu of Mines. For membership of the subcommittee, which changed somewhat from time to time, see Manning, *War Gas Investigations*, p. 4, and George A. Burrell, "The Research Division, Chemical Warfare Service, U.S.A.," *Industrial and Engineering Chemistry* (formerly *Journal of Industrial and Engineering Chemistry)*, 11 (1919), 93–94.

[11] Min, Mtg, NRC Subcomm on Noxious Gases, 21 Apr 17. War Gas Investigations, Bu of Mines.

Noxious Gases became less important as the war progressed and in August 1918 it was dissolved.[12]

Chemical Warfare Research in the Bureau of Mines

In expanding the activities of the Bureau of Mines into the field of chemical warfare, Manning's first step was to assemble a group of men to carry on the work. The leader of his staff was George A. Burrell, a consulting chemist who had formerly been with the bureau. Upon Burrell fell the responsibility of directing the building of the new research structure. Associated with Burrell were Arno G. Fieldner and J. W. Paul of the Bureau of Mines; Bradley Dewey, director of the research laboratory of American Sheet and Tin Plate Co.; Warren K. Lewis, professor of chemical engineering at Massachusetts Institute of Technology; and Yandell Henderson, professor of physiology at Yale University.[13]

As a first move these men marked out various lines of research based on reports from Europe to the Army and Navy. The most urgent task was the design of a gas mask for the Army. Other projects included study of the physiological effect of toxic compounds and the proper medical treatment for casualties, work on the preparation and properties of gases already in use on the battlefield, and the discovery of new toxic agents.

The bureau had neither the space nor the men to handle all the projects. As an emergency measure Manning obtained from the Subcommittee on Noxious Gases authority to accept offers of assistance from the Johns Hopkins University, the Mellon Institute, and other institutions. Manning then sent Dewey to seek co-operation from industrial and university laboratories in the West, and Lewis to laboratories in the East.[14] In addition Manning enlisted the aid of E. Emmet Reid, professor of organic chemistry at Johns Hopkins, who requested organic chemists throughout the nation to synthesize compounds that might be useful as agents.[15] By

[12] Manning, *War Gas Investigations*, p. 4.

[13] (1) Min, Mtg, NRC Subcomm on Noxious Gases, 21 Apr 17. War Gas Investigations, Bu of Mines. (2) A group photograph showing Manning with his staff, consultants, and advisory committee appears in *Armed Forces Chemical Journal*, IX (September–October 1955), 20–21.

[14] Ltr, George A. Burrell to the Director, Bu of Mines, 2 May 17, sub: Gases in Warfare. War Gas Investigations, Bu of Mines.

[15] (1) E. Emmet Reid, History of Offense Research, Johns Hopkins University Station. CWS, H–149. (2) E. Emmet Reid, "Reminiscences of World War I," *Armed Forces Chemical Journal*, IX (July–August 1955). 37–39.

the end of May 1917 the bureau had obtained the aid of laboratories in twenty-one universities, three industrial companies, and three government agencies, with a total of 118 chemists.[16] In time additional universities and firms volunteered for research projects. These civilian laboratories were extremely helpful, for they enabled the bureau to begin chemical warfare research immediately instead of waiting several months for a government laboratory to be equipped and staffed with chemists.

Up to 30 June 1917 the Bureau of Mines paid the cost of chemical warfare research from its own appropriations.[17] It engaged 16 men for physiological investigations on gases and masks, 20 to develop masks, 5 to work on munitions, 4 to prepare toxic agents and smoke, and several as supervisors and clerks.[18] After June the Army and Navy provided funds.

As chemical warfare research expanded the volume of work became so great that the bureau needed a large central laboratory for co-ordinating university and industrial research, and for undertaking secret Army and Navy projects. After examining several sites in the District of Columbia, in Delaware, and at Picatinny Arsenal in Dover, N.J., Burrell and his assistants finally chose American University, which the trustees had offered to President Wilson for government use on 30 April.[19] The university was then on the outskirts of Washington, and sufficiently isolated to be used as a training center for chemical troops and to permit field testing on a small scale. Two large buildings and several hundred acres of ground were available.

The War and Navy Departments in June allotted the Subcommittee on Noxious Gases $175,000 to convert American University classrooms into laboratories and to hire more chemists.[20] Several weeks later, on 21 July the trustees granted the government free use of the university.

Throughout the summer of 1917 contractors worked at the university, converting rooms into offices and laboratories. Temporary buildings, large and small, were erected to serve as workshops and as houses for workers and as shelters for animals. The War Department converted a section of the grounds into Camp Leach, where officers and enlisted men could learn the technique of chemical warfare.

[16] Rpt submitted at Mtg of Subcomm on Noxious Gases, 25 May 17. War Gas Investigations, Bu of Mines.

[17] Manning, *War Gas Investigations,* p. 1.

[18] Rpt, G. A. Burrell to the Director, Bu of Mines, 2 Jul 17, sub: Statement of Activities on Gas Work at the Present Writing. War Gas Investigations, Bu of Mines.

[19] Yandell Henderson, History of Research at Yale University, pt. 2, p. 3. CWS, H–150.

[20] Manning, *War Gas Investigations,* pp. 6–7.

BUREAU OF MINES EXPERIMENT STATION *for chemical warfare, American University, Washington, D.C., 1917. McKinley building (with dome) was then known as the Ohio building.*

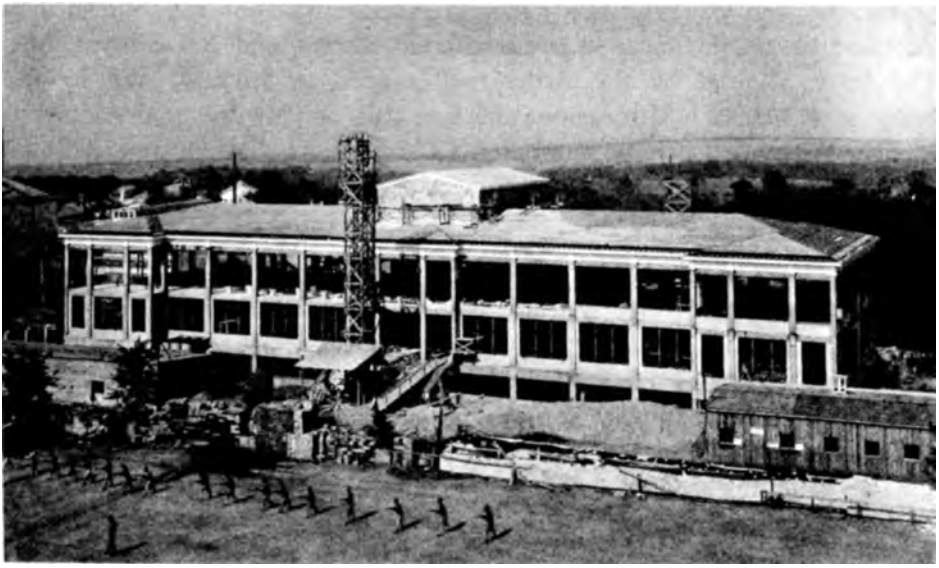
In September the first chemists arrived. The laboratories were not finished, there was no heat, and there was insufficient equipment. Yet, there were so many problems awaiting solution that chemists set up their apparatus on improvised benches while carpenters installed hoods and desks, plumbers laid gas and water lines, and electricians wired sockets.[21]

Shortly after the research center at American University opened, Manning organized it into eight sections: Chemical Research, Physiological Research, Pyrotechnic Research, Chemical Manufacture, Mechanical Research, Submarine Gases, Dirigible and Balloon Gas, and Gas Mask Examination.[22]

Liaison was maintained among the Army, Navy, and Bureau of Mines through frequent committee meetings and by personal contact between officers and members of the research staff. Twice a week, conferences were held between officers and scientists. One conference considered chemical warfare offense, the other, problems in defense. Twice each month a report was sent to the War Department, the Navy Department, the Ameri-

[21] Reid, "Reminiscences of World War I."

[22] Organization Chart dated 1 Sep 17. War Gas Investigations, Bu of Mines.



NEW CHEMICAL BUILDING AT AMERICAN UNIVERSITY *under construction for chemical warfare research. Note the class in bayonet drill, foreground.*

can Expeditionary Forces in France, and to British and French chemical warfare investigators.

By the fall of 1917 the bureau had the benefit of an increased flow of information from Europe. In the opening months of the war it had depended upon reports from special observers in Europe, such as Professor George A. Hulett of Princeton University, or upon information acquired by Army and Navy officers. Then in October, Maj. Samuel J. M. Auld, chemical adviser of the Third British Army, and a group of officers and NCO's came to the United States as part of the British Military Mission. Auld and his men gave information on toxics, chemical munitions, and protective equipment, and helped to lay out a chemical proving ground.[23] Also in October, the Army assigned an officer in London to the task of obtaining and sending home information on chemical warfare.[24] By these means the bureau learned of research being done by the Allies, and of new developments in enemy chemical warfare.

[23] A résumé of work done by the British may be found in the series of reports: British Gas Mission to the U.S.A., A General Record of the American Chemical Warfare Service and the Relations therewith of the British Gas Warfare Mission. CWS, H-1 to H-10.

[24] History of Chemical Warfare Service, American Expeditionary Forces, Liaison Office, London. CWS, H-24.

By the end of 1917 the chemical warfare staff of the bureau had increased to 277 civilians, 34 commissioned officers, and 200 enlisted men. The funds allotted by the Army had jumped to $612,000 and by the Navy to $150,000.[25] Throughout the first half of 1918 the staff continued to grow, and on 25 June numbered 1,682 persons, civilian and military, 1,034 of whom were classified as technicians.[26]

Medical Research

The Bureau of Mines was not alone in conducting chemical warfare research and development for the Army and Navy. The Medical Department, U.S. Army, also participated for a short time, taking over certain projects from the bureau, continuing them for awhile, and then surrendering them to the new Chemical Warfare Service.

The plans for medical research were drawn up by Professor Henderson of Yale University. Because there was no laboratory space available in Washington, Yale allowed Henderson to remodel the Athletic Club House into a laboratory and to use the athletic field.[27] Yale also built a laboratory beneath the bleachers, as the University of Chicago was to do some twenty-five years later at Stagg Field for research on the atom bomb. Faculty members of the university, medical students, and employees of the Bureau of Mines formed the staff. The men were divided into sections working on toxicology, therapeutics, pharmacology, pathology, and physiology. After space became available at American University, the bureau transferred much of the work to Washington.

By December 1917 medical research had become so diversified that Henderson and the section leaders began to hold monthly conferences in Washington. Known as the Medical Advisory Board, the group served as a clearinghouse for problems, ideas, and discoveries in the medical phase of chemical warfare.

Other university groups in addition to the one at Yale were drawn into medical research. In September 1917 professors and students at the University of Wisconsin began research on ways to protect the employees of poison gas factories.[28] At the University of Michigan, men studied the

[25] Rpt, Research Work of the Bureau of Mines on Gases Used in Warfare for the Year 1917. War Gas Investigations, Bu of Mines.

[26] Manning, *War Gas Investigations,* p. 10.

[27] Henderson, History of Research at Yale. H–150.

[28] History of the University of Wisconsin Section, Medical Division, CWS, H–151.

physiology and pathology of mustard gas poisoning.[29] At Western Reserve University, the University of Chicago, and the Marine Biological Laboratory at Woods Hole, Mass., scientists took up projects. In the spring of 1918 the Gas Defense Service of the Medical Department absorbed the majority of the laboratories.

Research in the AEF

The Bureau of Mines was too far from the battle zone to carry on research for the AEF, and General Pershing in the fall of 1917 requested the War Department on several occasions to furnish him with a laboratory service to investigate war gases and powders. On 1 November 1917 the War Department created a Chemical Service Section to comply with Pershing's request.[30] Col. William H. Walker, chief of the new section, took immediate steps to provide a laboratory for the AEF. Turning to Mellon Institute, Pittsburgh, Walker enlisted the co-operation of its director, Raymond F. Bacon, and its assistant director, William A. Hamor. Hamor, who was commissioned a major, had as his first important assignment the drawing up of plans for a laboratory for the AEF.[31]

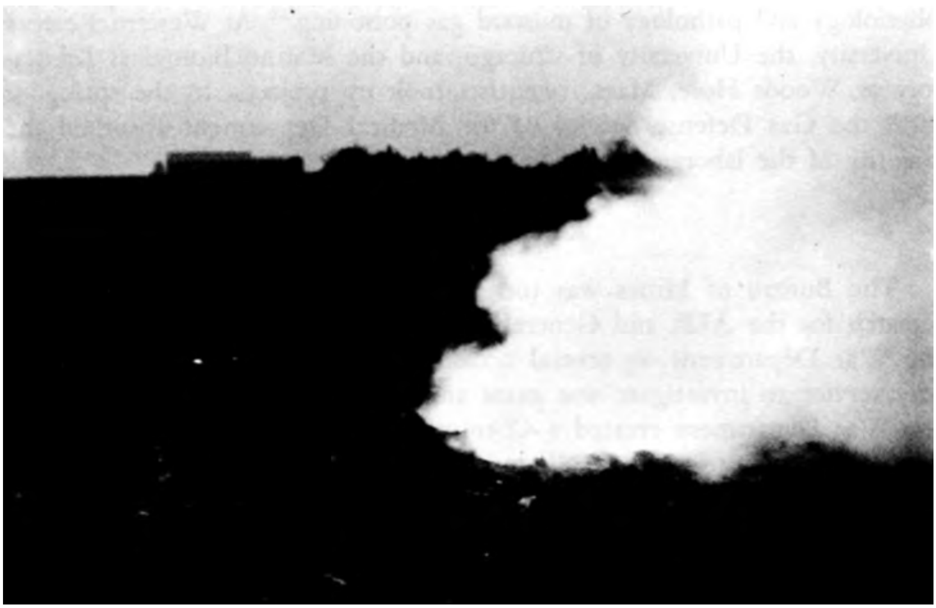
To obtain chemicals and equipment for the new laboratory, Bacon and Hamor turned to the president of the Fisher Scientific Company of Pittsburgh, Chester G. Fisher. Before World War I Germany was the world's chief source of chemicals and laboratory equipment and the Fisher Scientific Company depended on producers in Bavaria for its supply of these materials. After the outbreak of war in Europe in 1914 and the subsequent dislocation of shipping on the high seas, the Bavarian suppliers became very wary of making further shipments, and it was only with the greatest difficulty that Fisher Scientific got material through to Pittsburgh. But by an unusual stroke of fortune a considerable quantity of laboratory equipment arrived shortly before the entrance of the United States into the war. Fisher had this equipment on hand when Bacon and Hamor approached him late in 1917.[32]

[29] Aldred Scott Warthin and Carl Vernon Weller, *The Medical Aspects of Mustard Gas Poisoning* (St. Louis: C. V. Mosby Co., 1919).

[30] (1) Report of the Chemical Warfare Service, 1918, pp. 4–5. The annual reports of the CWS were also published as Report of the Director of the Chemical Warfare Service, Annual Report of the Chief of the Chemical Warfare Service, and Annual Report of the Chemical Warfare Service, all hereafter cited as Rpt of CWS, with appropriate year. (2) The Chemical Service Section is discussed at greater length in Leo P. Brophy and George J. B. Fisher, *The Chemical Warfare Service: Organizing for War,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1959), ch. I.

[31] Interv, Hist Off with W. A. Hamor, 30 Dec 58.

[32] (1) Interv, Hist Off with Chester G. Fisher, 30 Dec 58. (2) Hamor interv.



BATTERY OF LIVENS PROJECTORS *at Hanlon experimental testing field near Chaumont, France, 1918.*

The government made immediate arrangements for the Fisher Scientific Company to equip a laboratory for the AEF. All the apparatus which had recently arrived from Bavaria was put in wooden crates and shipped, along with chemicals, books, a glassworking shop, and another for instruments—seven full freight cars in all—to the Hoboken Port of Embarkation for shipment to France. Fisher obtained a written statement from the Chief of Staff, U.S. Army, that the shipment should be given a high priority. To accompany the laboratory overseas the Fisher Scientific Company furnished a glass blower, an instrument maker, a chief clerk, and a stock clerk.[33]

Meanwhile in France, Col. Amos A. Fries, head of the AEF Gas Service,[34] had obtained permission from the French Government to convert a former research laboratory for tuberculosis at Puteaux, near Paris, into a chemical warfare laboratory. In January 1918 Colonel Bacon, accompanied by a small group of chemists, arrived from the United States to head the laboratory. Since it would take several months for the equipment

[33] Fisher interv.

[34] General Pershing established the Gas Service to supervise chemical warfare activity in the AEF. AEF GO 31, 3 Sep 17.

from the United States to reach France, Colonel Bacon managed to obtain some laboratory supplies from French sources. Eventually other scientists arrived from the United States, so that the staff was to average between 60 and 70 chemists, approximately 12 of whom were commissioned officers. In this group were several men who were or later became famous in the field of chemistry—Gilbert N. Lewis, of the University of California, one of the world's outstanding physical chemists; Joel H. Hildebrand, a future president of the American Chemical Society; and Frederick G. Keyes, who became director of the research laboratory of physical chemistry at Massachusetts Institute of Technology.

The Paris Laboratory investigated a variety of chemical and physical problems having to do with toxic agents and protective devices, and also acted as a consulting laboratory for other nonchemical branches of the AEF.[35] For convenience the laboratory was divided into five divisions—Organic, Physicochemical, Mechanical, Control, and Miscellaneous. The organic chemists developed a systematic procedure for analyzing the contents of dud enemy chemical shells and of determining the agents present in contaminated water or earth. They synthesized possible war gases and searched for camouflage gases to simulate or conceal the characteristic odor of standard agents. For example, they learned that by adding butyl sulfide to it mustard gas gave out a strong skunklike odor; since much of the French countryside was infested by skunks the enemy was misled on the presence of gas. The physical chemists determined such important physical constants as density, vapor pressure, and rate of hydrolysis. The Control Section tested old and new gas mask canisters. The need for protection against mustard was so urgent that the sections collaborated in developing antimustard salves, a field detector for mustard, and protective fabrics. The Miscellaneous Section worked on problems submitted by other branches of the AEF, such as the development of a special airplane propeller glue for the Air Service and the production of a gasproof pigeon container for the Signal Corps.

Coupled to the Paris Laboratory was a field for experimental work and for training officers in gas warfare. Colonel Fries had asked for such an experimental field in December 1917. Receiving permission, he chose an area cov-

[35] (1) Col. Raymond F. Bacon, "The Work of the Technical Division, Chemical Warfare Service, AEF," *Industrial and Engineering Chemistry,* 11 (1919), 13–15. (2) Maj. W. A. Hamor and Col. R. F. Bacon, "A Letter from France," *Industrial and Engineering Chemistry,* 10 (1918), 495. (3) History of the Chemical Warfare Service, AEF Technical Division, Part I, General History. CWS, H–18. (4) History of the Chemical Warfare Service, AEF Technical Division, Part II, Paris Laboratory. CWS, H–19.

ering twenty square miles near Chaumont, headquarters of the AEF. He then sent officers to Porton, England, to learn how the British had laid out their experimental field and were conducting tests. The AEF started construction in April 1918, and the first tests were made in June. In August the installation was christened Hanlon Field in honor of 2d Lt. Joseph T. Hanlon of the First Gas Regiment, the first CWS officer killed in action.

Hanlon Field ultimately had two projector ranges, an artillery range complete with trenches, and fifty-five buildings, including chemistry, pathology, and physiology laboratories, a shell opening plant, and a shell filling plant.[36] Among the projects carried out were the testing of American equipment under battlefield conditions, examination of captured equipment, analysis of the chemical fillings in dud enemy shells, and physiological research.[37] From the viewpoint of organization, the Paris Laboratory and Hanlon Field were considered as the Technical Division of the AEF, Gas Service.[38]

The Centralization of Activities in the Chemical Warfare Service

A year after American entrance into the war, the Bureau of Mines, Medical Department, Ordnance Department, Signal Corps, Corps of Engineers, and AEF were sharing the responsibility for chemical warfare. The War Department had made an attempt in October 1917 to co-ordinate the activity by creating a Gas Service of the Army, headed by an Engineer colonel, Charles C. Potter, and composed of Medical, Ordnance, and Chemical Service Section officers. The Gas Service could offer advice, but it had no authority to control research, policy, or production. The service could therefore not bring about the high degree of teamwork that the War Department wanted.

Finally on 11 May 1918 the War Department placed Maj. Gen. William L. Sibert at the head of the Gas Service, and instructed him to

[36] Lt. Col. Joel H. Hildebrand, "The Organization and Work of Hanlon Field," *Industrial and Engineering Chemistry*, 11 (1919), 291–92.

[37] (1) History of the Chemical Warfare Service, AEF Technical Division, Part II, Hanlon Field. CWS, H-20. (2) Col. Raymond F. Bacon, "The Work of the Technical Division, Chemical Warfare Service, AEF." *Industrial and Engineering Chemistry*, 11 (1919), 13–15. (3) *Medical Aspects of Gas Warfare*, pp. 49–50.

[38] *United States Army in the World War, 1917–1919* (Washington, 1948), vol. 15, pp. 300–302.

draw up a plan for better co-ordination of chemical warfare. Sibert was certain that this could be done only by coalescing all men and facilities into one organization. He asked the War Department to transfer chemical warfare personnel from the Medical Department, Ordnance Department, Corps of Engineers, and Signal Corps to the Gas Service. There was no problem here. But Sibert also wanted the research organization of the Bureau of Mines, a request that was difficult for the War Department to fill. Sibert nevertheless persuaded Secretary of War Newton D. Baker that the move was necessary. Baker then attempted to convince President Wilson. Manning and his associates opposed the transfer vigorously.[39] President Wilson was reluctant, but finally agreed that the exigencies of war necessitated the move; and on 25 June 1918, under authority of the Overman Act, he placed the research organization of the bureau under the War Department "for operation under the Director of Gas Service of the Army." [40] The War Department commissioned Burrell as a colonel, and gave other research leaders corresponding rank. The militarization of the research organization did not affect the assignments of the scientists. They continued their work at American University and other laboratories.

On 28 June 1918 President Wilson approved Sibert's conception of a unified chemical warfare organization by directing the War Department to establish a Chemical Warfare Service in the National Army.[41] The new CWS included the Chemical Service Section of the Army, the research organization from the Bureau of Mines, and portions of the Ordnance Department, Corps of Engineers, Signal Corps, and Medical Department. Sibert organized the service into nine divisions: European, Medical, Training, Research, Administration, Gas Offense Production, Gas Defense Production, Development, and Proving.[42] Of the nine divisions in the new CWS, six sprang wholly or in part from the chemical warfare research organization started by the Bureau of Mines.

[39] (1) Memo on Gas War Work, Origin and Progress of Work and Comments Relative to the Transfer of this Work to the War Dept. 3 Jun 18; (2) Memo on Conference held in the Office of the Secretary of War, . . . May 25, 1918, regarding Proposed Transfer of the War Gas Investigations of the Bureau of Mines to the War Department. Both in War Gas Investigations, Bu of Mines.

[40] Wilson's Executive Order 2894, and a letter that he sent to Manning commending the Bureau of Mines, were widely reprinted. See, for example, *Industrial and Engineering Chemistry*, 10 (1918), 654.

[41] WD GO 62, 28 Jun 18.

[42] Rpt of CWS, 1919, p. 3.

Chemical Munitions [43]

Before the establishment of the CWS, responsibility for procuring and issuing chemical warfare items was divided between the Medical and Ordnance Departments of the Army. The Medical Department was assigned responsibility for defensive items and the Ordnance Department for offensive material. The Ordnance mission included the procuring, filling, and testing of toxic gases. The Army, of course, had never had occasion to purchase or produce poison gas. Its first step, therefore, was to choose the agents that would be used by the AEF. After evaluating the chemicals that had been used by armies in Europe, the Bureau of Mines recommended chloropicrin, hydrogen cyanide, phosgene, and xylyl bromide to the Ordnance Department in July 1917.[44] A few months later Colonel Fries sent recommendations from France that chlorine, phosgene, chloropicrin, bromoacetone, and mustard gas be procured.[45]

It was the intention of the War Department at the start of the war to arrange for the manufacture of toxic gases by commercial chemical companies under Ordnance Department supervision and to confine direct government activity to the filling of shells with toxic materials.[46] In the fall of 1917 the Ordnance Department set out to interest private industry in the manufacture of war gases and began to plan the erection of a shell filling plant near Edgewood, Md.[47]

Immediate responsibility for drawing up the plans was assigned to Capt. Edwin M. Chance, of the Trench Warfare Section, Gun Division of the Office of the Chief of Ordnance, then headed by Capt. E. J. W. Rags-

[43] Unless otherwise indicated this section is based on the following: (1) Benedict Crowell, *America's Munitions, 1917–1918* (Washington, 1919), pp. 395–410. (2) Lt. Col. William McPherson, An Historical Sketch of the Development of Edgewood Arsenal, 1 Feb 1919, pp. 290–344. CWS, H–169. (3) Report on Edgewood Arsenal, January 1919. CWS, H–168. (4) Lt. Col. Wilder D. Bancroft, History of the CWS in the United States, 31 May 1919, pp. 29–344. CWS, H–11. Col. F. M. Dorsey, "The Development Division, Chemical Warfare Service, U.S.A.," *Industrial and Engineering Chemistry*, 11 (1919), 281–91. (6) Charles H. Herty, "Gas Offense in the United States A Record Achievement," *Industrial and Engineering Chemistry*, 11 (1919), 5–12.

[44] (1) Ltr, Manning to Brig Gen William Crozier, 20 July 1917, War Gas Investigations, Bu of Mines. (2) Mustard gas, missing from this list, was not used until 12 July 1917, and the bureau did not know of the gas at the time. Later advice from abroad led to elimination of hydrogen cyanide. The recognition of the superior lachrymatory property of bromobenzylcyanide led to the abandonment of xylyl bromide.

[45] Fries and West, *Chemical Warfare*, pp. 100–102.

[46] Lt. Col. Edwin M. Chance, History of Edgewood Plants, p. 10. Colonel Chance submitted this report to the Assistant Secretary of War on 31 December 1918. See Ltr, Chance to Hist Off, 4 Feb 54.

[47] This property was acquired by the government under a presidential proclamation of 16 October 1917. It was at first called Gunpowder Neck Reservation and then Gunpowder Reservation. Later it took the name Edgewood Arsenal from the nearby village of Edgewood.

dale.[48] Captain Chance had the advice and assistance of Lt. Raoul E. Hankar of the French High Commission who supplied the plans of the French filling plant at Aubervilliers together with details on the properties of the gases to be filled. After careful examination of the data furnished by Lieutenant Hankar, Captain Chance concluded that the French methods were totally unsuited to American conditions, that the French production units were too small for production of good quality, and that their methods of handling the gases led to an unduly high casualty rate in French plants. Chance then decided to study the possibility of applying the methods of the commercial bottling industry to a gas filling plant and he visited a number of works where milk, beer, and carbonated liquids were bottled. Convinced that commercial methods could be adapted to gas filling plants, he drew up plans accordingly.[49]

BRIG. GEN. AMOS A. FRIES, *head of the AEF Gas Service. (Photo taken after July 1920.)*

Erection of the first shell filling plant at Edgewood, Md., was begun in September 1917 and practically completed by the close of the year. It consisted of four filling buildings radiating from a central powerhouse at 90-degree angles to each other. Each building was a complete unit in itself, with individual gas handling rooms, mixing rooms, washing towers, and ventilating equipment. If one building would have to be shut down because of an accident or for other reasons, it would be possible to keep the remaining units in production. The units were so constructed that the fan discharges were separated by a distance of over 400 feet, a precaution which prevented the accumulation of a dangerous concentration of gases during plant operation. This shell filling plant, known as Filling Plant No. 1, was completed by January 1918 and put into immediate operation. In the spring of 1918 construction got underway on two similar plants, both of which were approximately 80 percent complete by November. In

[48] The Trench Warfare Section, Ordnance Department, was organized in April 1917.
[49] Chance, History of Edgewood Plants, p. 1.

PLANT AT EDGEWOOD ARSENAL *where filled shells were classified, tested for leaks, painted, and boxed for shipment. Livens drums, foreground, were painted with two white stripes to indicate they were filled with phosgene.*

addition, two grenade filling plants and an incendiary-drop-bomb plant were either completed or were nearing completion when the war ended.

By the close of 1917 the War Department had come to the conclusion that the government would also have to erect its own manufacturing plants at Edgewood. The efforts of the Ordnance Department to interest the chemical industry in the manufacture of war gases had not proved successful because of the danger inherent in the manufacture of toxic materials, because industry lacked experience in the production of such materials, and because the toxic plants would serve no useful purpose after the war. During the unseasonably cold winter of 1917–18 a chloropicrin plant and a phosgene plant were built. In April 1918 construction was begun on a large-scale mustard plant and in the next month on a chlorine plant. The chlorine plant, which when completed had two 50-ton units with a total capacity of 100 tons of liquid chlorine a day, was the largest plant of its kind in the United States at that time. These plants collectively were on 4 May 1918 designated "Edgewood Arsenal," an installation of the Army Ordnance Department.[50]

[50] Ord Dept GO 7, 4 May 18.

In the construction and operation of the plants at Edgewood the Ordnance Department received valuable assistance from the Bureau of Mines and from representatives of the British and French Governments.[51] While this plant construction was going on at Edgewood, Ordnance continued to solicit the interest of private industry in the manufacture of toxic agents. The government decided to construct chemical plants at various points throughout the country and to urge the chemical companies to operate these plants. During the war a number of plants, including those operated by the government and those operated by contractors, were erected. (*Table 1*)

TABLE 1—PLANTS AND PROJECTS OF EDGEWOOD ARSENAL DURING WORLD WAR I

PLANT LOCATION	PROJECT	OPERATOR
Edgewood, Md	Manufacture of chloropicrin	Edgewood Arsenal.
Edgewood, Md	Manufacture of phosgene	Edgewood Arsenal.
Edgewood, Md	Manufacture of mustard gas	Edgewood Arsenal.
Edgewood, Md	Manufacture of chlorine	Edgewood Arsenal.
Edgewood, Md	Manufacture of sulphur monochloride.	Edgewood Arsenal.
Stamford, Conn	Manufacture of chloropicrin	Edgewood Arsenal.
Hastings-on-Hudson, N.Y	Manufacture of mustard gas	Edgewood Arsenal.
Kingsport, Tenn	Manufacture of bromobenzylcyanide.	Edgewood Arsenal.
Croyland, Pa	Manufacture of diphenylchloroarsine.	Edgewood Arsenal.
Willoughby, Ohio	Manufacture of lewisite	Edgewood Arsenal.
Niagara Falls, N.Y	Manufacture of phosgene	Oldbury Electro-Chemical Co.
Midland, Mich	17 brine wells for bromine supplies.	Dow Chemical Co.
Bound Brook, N.J	Manufacture of phosgene	Frank Hemingway, Inc.
Charleston, W. Va	Manufacture of sulphur monochloride.	Charleston Chemical Co.
Buffalo, N.Y	Manufacture of mustard gas	National Aniline & Chemical Co.

When the Chemical Warfare Service was activated in June 1918, a Gas Offense Production Division, with headquarters in Baltimore, Md., was

[51] Among those whose counsel was particularly valuable were Captain Hankar of the French High Commission, mentioned previously; W. Gordon Carey and T. D. Gregory, representatives of English firms engaged in the manufacture of toxic gases; Maj. G. M. Brightman and Lt. Col. Samuel J. M. Auld of the British Army. See acknowledgment in McPherson, An Historical Sketch of Edgewood Arsenal.

set up. This division, headed by Col. William H. Walker, former commanding officer of Edgewood Arsenal, took over from Ordnance the function of supervising the "production of toxic gases and other substances used offensively in gas warfare."[52] Edgewood Arsenal and its subsidiary plants were included in Colonel Walker's command.

By November 1918, the United States was manufacturing almost as much gas as England and France combined and nearly four times as much as Germany, which at the start of the war had led all other nations in the field of chemistry.[53] The manufacture and filling of gas at Edgewood Arsenal was carried out by the military because others lacked experience with that type of operation. A peak employment of over 7,000 officers and enlisted men was reached at Edgewood during the war. Government representatives were stationed at the various plants operated by the contractors, but civilians with some experience in the chemical industry were employed in the actual operation of those plants.

The plans for filling gas shells and shipping them across the ocean did not work out as expected. The chief difficulty was the extreme shortage of shell boosters.[54] At no time during the war did the supply of boosters come near meeting the demand. Consequently, the United States resorted to ocean shipment of bulk toxics, with more than 3,500 tons going to Europe. In England and France this gas was put into Allied shells and was eventually used against the enemy.

The implements which the U.S. Army employed to release gas on the enemy were obtained in great part from the Allies, particularly the British. These munitions included cylinders from which gas was dispersed and Livens projectors. Not until shortly before the armistice were these items received in the theater from the United States.[55] The delay was due in large part to the time required to get noncommercial items of this type into satisfactory production.

Gas Defense Equipment[56]

As early as the fall of 1915 the War Department delegated the task of designing, developing, and procuring gas masks to the Medical Depart-

[52] Rpt of CWS, 1918, p. 4.

[53] Rpt of CWS, 1919, p. 8.

[54] The booster, an explosive-filled metallic tube, was used as a burster to crack open the gas shell and free the gas.

[55] Fries and West, *Chemical Warfare*, p. 78.

[56] Unless otherwise indicated this section is based on the following: (1) Benedict Crowell, *America's Munitions*, pp. 410–31. (2) Bancroft, History CWS in the United States, pp. 85–103. (3) George A. Burrell, "The Research Division, Chemical Warfare Service, U.S.A.," *Industrial*

ment. Early in 1917 the Bureau of Mines offered its assistance in research and development, an offer which the Medical Department gratefully accepted. The bureau designed and tested masks in its own laboratories and co-operated with the following universities in experiments on absorbents for gas mask canisters: The Johns Hopkins University, the University of California, Princeton University, Wesleyan University, and the Carnegie Institute of Technology. In conjunction with the Bureau of Chemistry of the U.S. Department of Agriculture, the National Carbon Co., the National Lamp Works of the General Electric Co., as well as the University of Chicago, the bureau tested charcoal obtained from different woods, nuts, and seeds, and began to develop large-scale processes for carbonizing raw materials and activating chemicals. In the summer of 1917 much of this research and development work was transferred to the Medical Department. Bradley Dewey, who was then working with the Bureau of Mines, was commissioned in the Medical Department and put in charge of the gas mask program. Colonel Dewey became chief of the Gas Defense Production Division of the CWS upon its activation in June 1918.

The Medical Department received its first procurement directive for gas masks in May 1917. Twenty-five thousand were needed at once, the War Department stated, to equip General Pershing's First Division, then about to sail overseas. At the same time the Medical Department was directed to supply the armed forces with 1,100,000 masks by 30 June 1918.

Maj. L. P. Williamson of The Surgeon General's Office turned to the Bureau of Mines for assistance in filling the order for the first 25,000 masks. The bureau sought out and obtained the services of various manufacturers. The facepieces, for example, were manufactured by the B. F. Goodrich Co. of Akron and the canisters by the American Can Co. of Brooklyn. American Can also had the contract for assembling the masks. By June 1917 over 20,000 of the masks were at sea, bound for France, and some 5,000 followed shortly thereafter. The masks proved unsatisfactory, primarily because they did not protect the wearer against chloropicrin, which was beginning to be widely used. Since the British and French had more than enough masks, they readily

and Engineering Chemistry, 11 (1919), 93–104. (4) Bradley Dewey, "Production of Gas Defense Equipment for the Army," *Industrial and Engineering Chemistry*, 11 (1919), 185–97. (5) Dorsey, "The Development Division, Chemical Warfare Service, U.S.A.," pp. 281–91. (6) A. C. Fieldner and A. F. Benton, History of the Gas Mask Research Section, Research Division, Chemical Warfare Service, U.S.A. CWS, H–146. (7) Warren K. Lewis, "Protective Work in the Research Division, Chemical Warfare Service, in the War," *Chemical Warfare Bulletin* 18 (April 1932) pp. 1113–19 (a publication prepared by the CWS School, formerly *Chemical Warfare*).

supplied the American First Division with all it needed.[57] Although the 25,000 American masks were not used the experience resulted in improvement in the design of the mask.

The policy of obtaining masks exclusively through contract with private industry was continued throughout 1917. Contracts for procuring components of the mask were awarded to various manufacturers throughout the country, while a contract for assembling the parts into complete masks went to the Hero Manufacturing Co. of Philadelphia in the fall of 1917. From then until the end of the war Hero was the sole private contractor assembling masks. During the last months of 1917 transportation difficulties were aggravated by excessive snowfalls and the company experienced great delay in getting components from such points as Boston and Akron to Philadelphia. This was doubtless an important factor in the Hero's failure to attain scheduled production.

As early as mid-November 1917 the War Department had concluded that in order to meet the gas mask requirements for American troops being sent to France, as well as to insure the rigid standards demanded in this item of equipment, the government would have to construct its own gas mask factory. The site for the government factory was Long Island City, New York, where during the early months of 1918 the government took over a group of five large buildings and converted them into a factory.[58] A dollar-a-year man, Ralph R. Richardson of Chicago, was named plant manager with a lieutenant colonel as his assistant. The various departments in the plant were headed by either military or civilian personnel. Some 12,000 workers, of whom 8,500 were women, were at one time employed in the plant.

The government did not alter its plans of procuring masks from private industry after establishing the Long Island City plant, but on the contrary made every effort to step up production from private sources. The extent of private production during the war is indicated by the fact that the Gas Defense Division of the CWS at one time supervised contracts in approximately 600 factories extending from Boston to San Francisco.[59]

[57] This was but the beginning of American procurement of British and French masks in the AEF. Colonel Fries, upon assuming command of the Gas Service, AEF, in August 1917, began placing orders with the British and French in anticipation of the arrival of large numbers of American troops. About 200,000 masks were obtained from the French and not less than 600,000 from the British. See Amos A. Fries, History of Chemical Warfare Service in France, 1919, pp. 4, 9.

[58] The official directive for the activation of the government gas mask plant was Memo SW for SG, 20 Nov 17, sub: Establishment of Government Operated Plant for Gas Mask Manufacture. CWS, H-175.

[59] Rpt of CWS, 1919, p. 50.

WOMEN WORKERS IN GAS MASK FACTORY, *Long Island City, New York.*

Since the Army had no previous experience with gas masks, the contractors, as well as government officials supervising the contracts, had to learn largely through trial and error. One of the most baffling procurement problems in connection with the manufacture of the gas mask was that of obtaining sufficient charcoal for the canisters of the masks. Early in the war the War Department undertook a concerted drive to speed the shipment of coconut shells, from which the charcoal was made, from Ceylon, India, and other oriental countries to the Philippine Islands. There a government charcoal plant was erected which during 1917-18 produced 1,300 tons of coconut shell charcoal; 300 tons of this had been shipped to the United States by November 1918, but that amount was by no means sufficient to meet the demand. In the effort to find other sources of supply, the Gas Defense Division of the CWS sent agents to Mexico and to Central and South America to investigate ways of expediting the importation of coconuts into the United States. At the same time possible substitutes for the coconut shell were investigated. It was found that the corozo nut, the fruit of the Manaca palm tree, was the most suitable substitute and thousands of tons of these nuts were shipped into this country.

A colorful touch was lent to the search for carbon materials for the gas

mask in September 1918 when a nut gathering campaign was undertaken throughout the United States. The Red Cross, the Department of Agriculture, the Food Administration, and the Boy Scouts were among the groups sponsoring this venture. Two motion picture reels depicting the urgent need for charcoal were made and given wide circulation. By the close of the war on 11 November an estimated 4,000 tons of nut shells were en route to the great carbon plant at Astoria on Long Island.

This carbon plant was established in 1917 to activate charcoal, an even more difficult problem than the making of the charcoal itself.[60] The activation had to be done in facilities permitting fine control of temperature, and the government spent over $1,000,000 in constructing the Astoria plant. This facility was erected adjacent to the large gas works of the Astoria Light, Heat, and Power Co., at the junction of the East River and Long Island Sound, the point known as Hell Gate.

The first gas masks of export standard were sent overseas in January 1918, although not until May were they shipped in large numbers.[61] By November some 4 million masks had been shipped, together with considerable quantities of other gas defense items. (*Table 2*) Among these were bleaching powder, used to decontaminate gassed areas; extra antidimming, used to prevent moisture from condensing on gas mask eyepieces; sag paste, a protective ointment; dugout blankets, which were hung at the doors of dugouts as a protective device; dugout-blanket oil, a special heavy oil used to impregnate cotton blankets; warning devices, such as Klaxon horns and watchmen's rattles; and trench fans, to draw gases out of dugouts and trenches.

Field Testing of Chemical Munitions

While drawing up plans for a shell filling plant in the fall of 1917, the Ordnance Department began to consider the establishment of a proving ground where gas shells could be tested under simulated battle conditions. The Bureau of Mines co-operated by providing a competent scientist, William S. Bacon of the Yale section, to take charge of the program.[62]

[60] Activated charcoal is a specially treated, extremely porous charcoal which is very effective in absorbing chemical agents.

[61] Fries, History of Chemical Warfare Service in France, p. 9.

[62] (1) Bancroft, History of the CWS in the United States, pp. 345–60. (2) Lt. Col. William S. Bacon, "The Proving Division, Chemical Warfare Service, USA," *Industrial and Engineering Chemistry*, 11 (1919), 513–16. (3) History of the Proving Division, Chemical Warfare Service. CWS, H–70.

TABLE 2—GAS-DEFENSE ITEMS SHIPPED OVERSEAS FROM JUNE 1917 TO NOVEMBER 1918

Item	Unit	Quantity
Respirators (Gas Masks)	each	3,938,808
Extra Canisters	each	1,805,076
Horse Masks	each	351,270
Bleaching Powder	tons	1,867
Extra Antidimming	tubes	2,855,776
Sag Paste	tons	915
Dugout Blankets	each	36,221
Dugout-Blanket Oil	gallons	5,000
Warning Devices	each	19,620
Trench Fans	each	27,690

Source: This table appears in Annual Report of the Director, CWS 1919, p. 51, and in Crowell, *America's Munitions*, p. 431.

The British, who maintained a chemical proving ground at Porton, England, contributed the services of Maj. H. R. LeSueur, who helped lay out the grounds and organize the tests.[63]

The Ordnance Department started construction of a proving ground at Edgewood near the shell filling plant in January 1918. A month later the department stopped work at Edgewood because it was felt that the location was not sufficiently isolated and started anew in the pine forests near Lakehurst, N.J.

At Lakehurst, Ordnance constructed ranges, impact areas, laboratories, magazines, gun emplacements, observation towers, animal houses, barracks, and other buildings necessary for successful operation of a proving ground. To determine the quantity of gas present after explosion of a shell, Ordnance laid out two lines of trenches with dugouts and designed an automatic sampling apparatus to collect gas laden air in glass bottles located within the area.

The proving ground was manned by Medical, Ordnance, and Quartermaster officers and men. Tests were carried out jointly by chemists, physiologists, and meteorologists. The first gas shells fired in the United States were discharged at Lakehurst on 25 April 1918. Thereafter firing trials were made to determine the extent of decomposition of toxic agents during the explosion of shells, to ascertain the relative effectiveness and per-

[63] Maj H. R. LeSueur, British Gas Warfare Mission to the USA, Section VII, Work of the Lakehurst Experimental Station. CWS, H-6.

sistency of mustard, to find the number of shells necessary to build up a concentration of gas in a given area, to test experimental shells, and to test representative samples from the production line.

Demobilization

With the coming of peace in November 1918, the industrial and collegiate laboratories assisting the CWS dropped war projects and returned to their normal scientific research. At American University the volume of research subsided as the staff of more than twelve hundred technical men, among whom were many of the finest chemists in the United States, dwindled away until only a handful were left. The dismemberment of the service proceeded so rapidly that by 30 June 1919, 97 percent of its military personnel had been demobilized.[64] In a short time the CWS would have disappeared completely had not Congress on 11 July 1919 ordered the War Department to retain the service as an independent branch of the Army for another year.[65] Under the National Defense Act of 1920 the CWS became a permanent branch of the Army.[66]

For several months after the war the CWS retained the wide authority granted by the War Department in 1918 to carry on "all investigation and research work in connection with gas warfare." [67] In reality this meant little because the small staff could not cope with all projects relevant to chemical warfare. The only projects carried on were the development of boosters for gas and smoke shells, and the determination of bursting charges.[68] Shortly after Congress extended the life of the CWS in July 1919, the War Department issued the first peacetime instructions concerning research and development. The Department did not insist that the Chief keep up the wartime level of research and development, but it did require him to maintain a "competent body of chemical warfare specialists with facilities for continuous research and experimentation," and to keep "in touch with civilian agencies for chemical research and chemical industries capable of being converted for the production of wartime material." [69]

[64] Rpt of CWS, 1920, p. 13.
[65] (1) 41 *U.S. Statutes at Large* ch. IV p. 219. (2) WD Bull No 23, 19 Jul 19.
[66] P.L. 242, 66th Cong., Sec 12a.
[67] WD GO 62, 28 Jun 18.
[68] Rpt of CWS, 1920, pp. 23–24.
[69] Instructions from the War Department to the Chief Chemical Officer, 28 Nov 19. Cited in Rpt of CWS, 1920, p. 5.

There was little else that the CWS could have done at this time even had it desired. The government had returned American University to the trustees, and the Research Division of the CWS was busy preparing new laboratories at Edgewood Arsenal and transferring equipment and records. CWS scientists, uncertain of their future, were not disposed to remain, so that between 1 July and 1 November 1919 there was only an average of eighteen technical men to keep the work alive.[70]

The central gas mask factory at Long Island City was demobilized after the war. This was done on a gradual basis, each employee being discharged only after he had been placed in other civilian employment.[71] A second demobilization project was the termination of over twelve hundred formal contracts and over fifty informal contracts. By 1 July 1920 all CWS formal contracts and over 98 percent of the informal contracts had been settled.[72]

More time consuming was the sale of the surplus chemical plants and surplus items of chemical warfare equipment and matériel. By 1 July 1920 the plants had either been sold or transferred to other government bureaus, and by that time also great quantities of surplus matériel had been sold.[73] But disposition of some World War I surplus property continued into 1925.[74]

Certain matériel that might prove useful in peacetime was not declared surplus, notably the gas mask. Planners realized that a number of masks would be needed for training purposes in peacetime as well as for war reserve. Not only would World War I masks have to be reconditioned, but it would also be necessary to manufacture improved masks during the peacetime years. Thus within a year after the signing of the armistice it was decided that a government-owned, government-operated gas mask factory would be built at Edgewood Arsenal, to be equipped with machinery used in the Long Island City plant.[75]

Much of this machinery had been sold as surplus after the war and the remainder shipped for storage to the government plant at Hastings-on-Hudson, N.Y. In late 1919 and early 1920 this machinery was transferred to Edgewood, where it was installed in the new gas mask factory.

[70] *Ibid.*, p. 29.
[71] Rpt of CWS, 1919, p. 51.
[72] Rpt of CWS, 1920, p. 16.
[73] Rpt of CWS, 1920, p. 15.
[74] Rpt of CWS, 1920, p. 17.
[75] Rpt of CWS, 1920, p. 30.

A more difficult problem was that of securing operators to run the machinery, for although a number of the supervisors from the Long Island plant came to Edgewood very few of the operators did. Consequently, it was necessary to train new operators, a process which required a period of about six months.[76] The gas mask factory at Edgewood reconditioned approximately one half million World War I masks and produced 120,000 new masks in the years 1920–21.[77]

With the armistice the staff of the proving ground was quickly demobilized. In November 1919 the CWS established an officers' training school at Lakehurst, where shortly afterwards the First Gas Regiment was stationed. In the spring of 1920 the service resumed testing operations.[78]

During the twenty months in which the United States was involved in World War I, the Bureau of Mines and the Army built up the largest organization of scientists ever assembled in this country, perhaps in the world. The volume of research carried on by these scientists was tremendous and their contributions notable.[79] One group, headed by Capt. Winford Lee Lewis, of Northwestern University, discovered lewisite and another group under Maj. Roger Adams, of the University of Illinois, produced adamsite. Some scientists carried on extensive research on protective equipment and chemical warfare weapons. In medical research, physiologists studied the reaction of chemical agents upon the body, so that methods of treatment could be devised.

When the War Department launched the program to produce gas warfare munitions, neither the military establishment nor American industry had had any experience in manufacturing gas warfare items. Under these conditions it is surprising that so much gas warfare equipment was manufactured and that such a large portion of it was delivered to the theater by the close of the war.

Yet the amount of such equipment reaching France was only a fraction of what the troops needed and the U.S. Army therefore had to rely on the French and the British to fill the bulk of its needs. This situation was not confined to gas warfare items by any means; throughout 1917 and 1918, the AEF depended upon the French and British for almost every

[76] Rpt of CWS, 1921, p. 23.

[77] (1) Rpt of CWS, 1920, p. 31. (2) Rpt of CWS, 1921, p. 24.

[78] (1) Rpt of CWS, 1920, pp. 39–40. (2) *Annual Report, Edgewood Arsenal, Md. and Lakehurst Proving Ground, Lakehurst, N.J.* FY 1921, pp. 26–28. CWS 314.7 Early CWS History File.

[79] A partial report on the work of the scientists is the 50-volume series of chemical warfare monographs completed in 1919.

Ordnance item except rifles and small arms ammunition.[80] The implications of this experience were not lost on the War Department or on the Congress, and in the 1920 revision of the National Defense Act provision was made against future emergencies through the inauguration of a system of industrial mobilization planning.

[80] Constance McLaughlin Green, Harry C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1955), p. 24.

CHAPTER II

Research and Development in Peace and War

Chemical warfare research and development dipped to its lowest point at the end of 1919. At this time the service was still a temporary wartime organization, with no guarantee that Congress would pass legislation making it a permanent branch of the Army. But word finally filtered down to Brig. Gen. Amos A. Fries, who had succeeded General Sibert as chief on 28 February 1920, that the legislators would probably continue the CWS, and Fries began to rebuild its organization. He revamped the Office of the Chief in Washington, establishing a Technical Division to act as his staff in matters concerning research and development.[1] A year later he added a Medical Division, headed by an officer from the Medical Department, to supervise medical investigations relating to chemical warfare and to act as liaison with the Public Health Service, the Veterans' Bureau, and the Army and Navy Medical Departments.[2]

Since the CWS had been formed as a service organization to all other branches of the Army, close liaison with them was essential in order to meet their requirements. To fulfill this function General Fries established the Chemical Warfare Technical Committee (CWTC) in March 1920, composed of officers of the CWS and of all combatant branches interested in chemical munitions.[3] After the CWTC was formed its duties were ex-

[1] (1) Rpt of CWS, 1920, p. 5. (2) The responsibilities of the Technical Division are given in Pamphlet, Organization of the Office of the Chief of Chemical Warfare Service, 7 Nov 21, pp. 5-7. CWS 314.7 Early CWS History File.

[2] The responsibilities of the Medical Division are given in: (1) Pamphlet, Organization of OC CWS, p. 7. (2) Rpt of CWS, 1921, pp. 13-14.

[3] OC CWS SO 74, 31 Mar 20.

panded to include the preparation of the project program for chemical warfare matériel. To handle the development of matériel intended for use by CWS troops only, General Fries set up a similar group composed of CWS personnel and called the Chemical Warfare Branch Committee.

To the American Chemical Society, which had provided an advisory committee to assist the CWS during the war, General Fries went with a request for another committee to consult with him on scientific matters. The society appointed a group of outstanding chemists who met periodically with General Fries and with later chiefs to discuss chemical warfare and to recommend promising lines of research, changes in organizational structure, and possible solutions to vexing chemical warfare problems.[4] Through this organization the CWS had access to the best minds in American chemistry.

In reorganizing Edgewood Arsenal, General Fries provided for two technical groups: the Chemical Research and Development Division (later the Chemical Division) to investigate smokes, incendiaries, and toxic agents; and the Mechanical and Electrical Research and Development Division (later, the Mechanical Division) to design munitions and masks.[5] In 1921, when the War Department ordered the CWS to remove its wartime proving ground from Lakehurst, N.J., General Fries set up a Proof Department at Edgewood.[6] The following year he completed the basic technical organization at the arsenal by adding a Medical Research Division to determine the toxicological and physiological action of chemical compounds, to develop methods of treating chemical warfare casualties, and to instruct officers in the medical aspects of chemical warfare.

Fries kept the Chemical and Mechanical Divisions and the Proof Department at Edgewood in the normal command channels, but because of the highly technical nature of their work he placed them under a Technical Director, the first of whom was Dr. James E. Mills, appointed in April 1921.[7] The Medical Research Division, on the other hand, remained under an officer of the Medical Department.

General Fries did not alter the research organization for several years,

[4] (1) The original members of the ACS advisory council are listed in Rpt of CWS, 1920, p. 18. (2) For the history of the advisory council see Carl B. Marquand, The American Chemical Society Committee and its Relation to the Chemical Corps, 1955. CWS 314.7 ACS File.

[5] Rpt of CWS, 1920, p. 26.

[6] (1) Rpt of CWS, 1921, pp. 29–31. (2) *Annual Report, Edgewood Arsenal, Edgewood, Md., and Lakehurst Proving Ground, Lakehurst, N.J.*, 1921, pp. 7–8, 26–28.

[7] (1) Rpt of CWS, 1921, p. 17. (2) A brief account of James E. Mills may be found in "Au Revoir, Dr. Mills," *Chemical Warfare Bulletin* 15 (July 1929), 606–07.

but in the meantime he established a Chemical Warfare Board, which came to play a part in the technical program. The board, composed of seven officers, was created in 1923 for the purpose of outlining broad policies and shaping them in definite form for the chief chemical officer.[8] In 1926 Fries reorganized the board, reduced its membership to four officers, and stationed it at Edgewood Arsenal.[9] A primary function of the board now was to study and co-ordinate the technical developments of the CWS with tactical doctrines and methods.[10] In carrying out its mission the board conducted or supervised service tests of equipment used by chemical troops and studied proposed projects before they were acted upon by the Chemical Warfare Technical Committee.[11]

With the addition of the board to the other technical agencies, which included the medical and technical staffs in the Office of the Chief, the laboratories and shops at Edgewood Arsenal, the CWTC, and the American Chemical Society advisory committee, the basic research and development organization of the CWS was complete. The organizational structure, however, still did not satisfy General Fries. Edgewood Arsenal had grown and the projects had increased since 1920, bringing a certain amount of unwieldiness in operations. In the autumn of 1928 he divided the three technical divisions, Chemical, Mechanical, and Medical, into six divisions—Research, Munitions Development, Protective Development, Engineering, Medical, and Information. Each division, in turn, was made up of several departments.[12] The Research Division consisted of an Organic Department, which synthesized new compounds and investigated manufacturing processes on a small scale; a Physical Department, which made fundamental studies of smokes, charcoal, and filtration; and an Analytical Department, which performed routine analyses and identified new substances. The Medical Division had two branches: a Toxicological Department, which determined the toxicity of substances and conducted fundamental research on toxicity; and a Medical Department, which studied physiological action and mechanism of chemical warfare agents and developed first-

[8] OC CWS SO 19, 21 May 23.

[9] OC CWS SO 59, 19 Nov 26.

[10] AR 50–10, 3 Jan 27.

[11] (1) "The Chemical Warfare Board," *Chemical Warfare Bulletin* 12 (December 1926), p. 1. (2) Rpt of CWS, 1928, p. 20. (3) Ltr, Maj E. Montgomery to C CWS, 5 Jan 27, sub: Procedure in Development, Test and Adoption of Chemical Warfare Materiel, with 3 Inds. Edgewood Arsenal (EA) 400.112/2. Copy in CWS 314.7 Early CWS History File.

[12] (1) Capt Maurice E. Barker, "The Technical Divisions, Edgewood Arsenal," *Chemical Warfare Bulletin* 15 (July 1929), 607–10. (2) CWS News Letter, no. 1, 1 Jan 29, pp. 1–2. Technical Library, A CmlC, Md. (3) For charts see Rpt of CWS, 1931 (secret supplement).

aid treatment. The Munitions Development Division consisted of a Munitions Department, which developed grenades, bombs, candles, and shells; a Weapons Department, which developed mortars, Livens projectors, large-area smoke screen generators, airplane spray tanks, and gas cylinders; and a Plants Department which developed, constructed, and operated pilot plants and full-scale toxic and impregnite plants. The Information Division had three units—a Technical Files Department to handle files and prepare monographs, a Technical Library Department, and an Editorial Department to edit research and development reports. The Protective Development Division consisted of a Protective Clothing Department, which developed protective clothing and methods of decontamination; a Gas Mask Department; and a Collective Protection Department. The Engineering Division was divided into a Design Department, which prepared designs, drafts, and specifications; a Physical Testing Department, which conducted physical tests on materials; a Shops and Loading Department, in charge of machine shops and surveillance facilities; the Field Testing Department, which conducted all tests in the field, and a Photography Department. After the reorganization of 1928, the technical structure of the CWS remained much the same until World War II.

The Peacetime Scientific Program

At the time of the Congressional action of 1920, service scientists had no official project program. The CWTC several months earlier had drawn up a list of projects which General Fries submitted to the War Department, and while the Secretary of War was studying the matter, scientists at Edgewood and Lakehurst continued to work on problems that had been left unfinished at American University. In December 1920 the Secretary approved Fries' program, under which scientists were to concentrate on perfecting unsatisfactory wartime implements and then, as salvage operations were completed, to turn to the investigation of new items. In this way Fries planned to improve the inferior chemical warfare items that had been produced during war, thus saving the cost of new equipment and at the same time providing the Army with a reserve of chemical warfare supplies for training and emergency use. By the end of fiscal year 1921 the salvage operations were largely completed and a number of new projects had been started.[13]

[13] Rpt of CWS, 1921.

During the period from 1920 to 1940 the CWS initiated approximately 700 projects for the Army, the Navy, and for civilian organizations. The military subjects encompassed gas masks, protective clothing, protective ointments, incendiary materials, mortars, airplane spray tanks, chemical cylinders, chemical artillery shells, colored smoke, chemical grenades, toxicological studies, meteorology, analytical methods, pilot plants, full-scale plants, filling plants, and medical studies.

In the 1920's the CWS placed emphasis on long-range projects.[14] During these years Capt. Louis M. McBride, Dr. G. S. Maxwell, and their co-workers made radical improvements in the mortar, greatly increasing its range and accuracy. Dr. James E. Mills applied the theory of probability to the study of toxic compounds, and pointed the way to better methods of determining toxicities. Dr. Leo Finkelstein conducted fundamental research on the filtration of aerosols to improve the smoke retaining properties of gas mask canisters.

In the 1930's the CWS de-emphasized long-range research and concentrated on filling the gaps in chemical warfare equipment. This involved the development of new items, the redesigning of chemical plants to conform to modern engineering practice, and the drawing of specifications needed from the procurement of matériel.

While the CWS placed a large number of projects on its technical program, the research organization itself was not large. The service received very small appropriations from Congress (from 1923 to 1926, less than a million dollars a year; from 1927 to 1938, less than two million; in 1939 and 1940, between two and three million), and thus it was severely limited in the funds it could spend on research and development.[15] As a consequence some of the projects received only a few hundred dollars, with the average only a few thousand.

Although the primary purpose of the CWS was to produce implements of war, the service took every opportunity to volunteer its facilities and staff to assist civilian groups in carrying out special scientific studies. Among these projects were: Rat Extermination (1921), War Gases as Insecticides (co-operative project with the Bureau of Entomology, 1922), Apparatus for Toxicological Experiments (co-operative project with the Bureau of Entomology, 1922), Extermination of Locusts (co-operative project with the Philippine Islands Department of Agriculture, 1923), Ex-

[14] Duncan MacRae, "The Scientific Approach to Military Problems," *Armed Forces Chemical Journal,* V (January 1952), 26–27.

[15] Brophy and Fisher, *Organizing for War,* ch. 2.

termination of Field Rats (co-operative project with the Hawaii Sugar Planters' Association, 1923), co-operative project with the Biological Survey (1923), Marine Piling Investigation (1923), and Boll Weevil Investigations (1920–27). These projects were generally financed by Congress or some agency of the government since the CWS did not have funds to underwrite extracurricular research.[16]

The longest and most important of these investigations was the search for a boll weevil insecticide. Shortly after World War I, the weevil seriously menaced cotton crops in the South. In July 1920 the CWS made arrangements to test toxic war agents as insecticides on the farm of the State Board of Entomology, Baxley, Ga. While the agents destroyed the weevils, they also injured the cotton. Chemists then prepared a series of compounds and mixtures which they tested at Tallulah, La.; the South Carolina Experiment Station, Clemson College, Clemson, S.C.; the Florida Experiment Station, Gainesville; Experiment, Georgia; and Auburn, Ala. Out of thousands of poisonous mixtures, the CWS found several that could be produced commercially and were acceptable to the farmer.[17]

Another investigation of considerable importance concerned the protection of submerged wooden pilings against marine borers. The Committee on Marine Piling Investigation of the Division of Engineering and Industrial Research, National Research Council, arranged for the Department of Commerce, the Bureau of Yards and Docks, and the Quartermaster Corps to pay for the cost of the work. The CWS carried out laboratory experiments at Edgewood Arsenal and at the Bureau of Fisheries, at Beaufort, N.C., to find poisons that would kill or repel shipworms, and other borers. Then it soaked sections of railroad ties with these poisons, and exposed them to borers in the harbor at Beaufort and at Pearl Harbor. Through this procedure, the service found a number of substances for treating wood that was to be submerged under water.[18]

The CWS and the Public Health Service co-operated in developing an alarm for deadly hydrogen cyanide fumigating gas. They did this by add-

[16] Résumés of nonmilitary research may be found in: (1) Maj. Gen. Amos A. Fries, "By-Products of Chemical Warfare," *Industrial and Engineering Chemistry,* 20 (1928), 1079–84. (2) Carl B. Marquand, "Contributions To Better Living From Chemical Corps Research," *Journal of Chemical Education,* 34 (1957), 532–35.

[17] (1) H. W. Walker, "A Brief Résumé of the CWS Boll Weevil Investigation," *Chemical Warfare Bulletin* 13 (December 1927), 231–37. (2) James E. Mills and H. W. Walker, Chemical Warfare Service Boll Weevil Investigation. EACD 485, Aug 1928.

[18] (1) William G. Atwood and A. A. Johnson, *Marine Structures; Their Deterioration and Preservation* (Washington: National Research Council, 1924), pp. 165–220. (2) Maj. Gen. Amos A. Fries, "Summary of Marine Piling Investigation," *Military Engineer,* 17 (1925), 237–39.

ing tear gas to the odorless cyanide. The tear gas would quickly drive away anyone who might accidentally enter an area under fumigation.[19] For the Navy the CWS worked on a special paint to prevent barnacles and other marine growths from fouling the bottoms of ships.[20] CWS protection experts also developed ammonia masks for workmen in ice plants, carbon monoxide masks for industrial firms, and fumigation masks for the Public Health Service. After a disastrous fire at the Cleveland Hospital Clinic on 15 May 1929, in which many of the 125 dead were suffocated by gases from burning X-ray film, the CWS studied the factors involved in the combustion of film and then widely publicized the danger of improper storage conditions.[21]

The value of this nonmilitary research could not be measured in dollars, but men within the CWS felt that its peacetime benefits to the nation were greater than the cost of its program.

Development Procedure

All research and development carried on by the CWS, whether for civilian or military purposes, and along chemical or mechanical lines, differed from academic research in that it aimed at definite, practical goals rather than the discovery of new scientific principles. In this sense it was akin to industrial research and development, which also sought the development of goods for a definite purpose, the consumer market. But even so the course of development followed by the CWS was painstaking and rigorous because it was directed toward the production of equipment upon which lives and battles might depend. The War Department, on the other hand, ordered the process to be carried out as expeditiously as possible: "The desire for perfection in any item of equipment must not delay the designation as standard type of at least one adopted type of every required article of equipment so that in any case of an emergency the procurement program may be launched without delay." [22] In the laboratories and shops

[19] (1) H. W. Houghton, New Method for Ship Fumigation. EACD 200, 3 Aug 42. (2) C. D. Quick, Additional Investigation on the Hydrocyanic Acid—Cyanogen Chloride Fumigation Mixture. EACD 294, 31 May 23.

[20] (1) Byron L. Wehmhoff, Albert M. Jordan, and Harry C. Knight, "Hot Plastic Shipbottom Paint," *Chemical Warfare Bulletin* 15 (December 1929), 675–80. (2) "Chemical Warfare Vs. the Barnacle," *ibid.*, 14 (July 1928) 369–71.

[21] *Proceedings of a Board of the Chemical Warfare Service appointed for the purpose of investigating conditions incident to the disaster at the Cleveland Hospital Clinic, Cleveland, Ohio, on May 15, 1929* (Washington, 1929).

[22] AR 820–25, Par. 15.

this was translated into the motto: "Strive for practicability rather than perfection." [23]

In passing from the original idea to the final product, the CWS employed a procedure based upon regulations laid down by the War Department.[24] The idea itself could stem from the laboratories at Edgewood, a CWS officer, another branch of the Army, or a patriotic civilian. It was then studied in the Office of the Chief and perhaps by the Chemical Warfare Board. If the idea was accepted the Technical Committee drew up a military requirement, an official statement that the proposed article was needed by the Army, and the military characteristics, a list of specifications that stated the desired size, shape, weight, materials of construction, and performance of the finished article. After approval of the requirements and characteristics by the Chief, CWS, and the War Department, Edgewood Arsenal went to work.

The first step was a preliminary investigation in the library or the laboratory to see what had been done by others along the same line, and to aid in analyzing the problem. With this information the staff drew up a project specification outlining the problem and estimating the time and money required. Then the technical experts took over, constructing and testing a series of models until they produced one that fulfilled the military requirements and characteristics. The Chemical Warfare Board tested the article under simulated service conditions and recommended any improvements that were needed. The laboratories made the improvements, the Board tested the equipment again and gave its approval. The CWS canvassed industry to make certain that materials and facilities were available to produce the munition in wartime quantities. Finally, when the article was known to be satisfactory for use under field conditions and procurable in the required quantities, it was cleared through the War Department and designated as a standard item of equipment. The procedure varied slightly when the request for the development of an item came from an-

[23] Intervs, Hist Off with Dr. Frederick W. Lane and Mr. Harry C. Knight, 22 May 57.

[24] (1) Pamphlet, Edgewood Arsenal, the Seat of Chemical Warfare, pp. 7–10. (2) Instructions from Chairman CWTC, Principles that Should Govern in the Research and Development of Materiel and Ammunition Pertaining to the Chemical Warfare Service, 30 Mar 22. (3) Maj Earl J. Atkisson, Policy Governing Research and Development, 19 Jul 22. All in CWS 314.7 Early CWS History File. (4) Pamphlet, Procedure in Development, Test and Adoption of Chemical Warfare Material, approved 31 Jul 26, corrected to 29 Aug 27, and revised edition, 6 Sep 29. (5) Pamphlet, Development Procedure, 16 Dec 31, and revised edition, 1 Feb 38. All in CWS Publications File, Technical Library, A CmlC, Md. (6) Rpt of CWS, 1920, p. 29. (7) Rpt of CWS, 1931 (secret supplement), pp. 17–20. (8) Barker, "The Technical Divisions, Edgewood Arsenal."

other branch of the Army or from the Navy. In this case the ultimate user set forth the desired characteristics and tested the equipment.

Maj. Gen. Harry L. Gilchrist, chief of the CWS from 1929 to 1933, estimated that in time of peace ten years were required to go through the normal development cycle of research (two years), development (three years) adoption (one year), and supply and improvement (four years).[25] Much of this time was spent in funding, delays in authorization, staffing, procurement of materials, and administrative work, rather than in laboratory and test work. During World War II the CWS had to telescope the procedure and take short cuts in order to supply the Army, Navy and Air Forces with the weapons they wanted. But this speed, particularly in the early days of the conflict, frequently resulted in items that had not been sufficiently tested in the engineering process or in the field and consequently were not entirely suitable.

Laboratories and Proving Grounds

In the 1920's and 1930's the CWS had to creep along, but the outbreak of war in Europe changed matters. The Congressional appropriation jumped from approximately two million dollars in 1940 to more than sixty million in 1941. To handle the new problems that arose, the CWS scientific organization had to expand enormously.

In 1940 the CWS carried on all research and development at Edgewood Arsenal, mainly in buildings dating from World War I. The old laboratories had been suitable for the small-scale operations characteristic of the 1920's and 1930's, but not for the tremendous volume of technical work necessary to support the armed forces in World War II. The service drafted plans for a chemical research laboratory and a medical research laboratory at Edgewood. Since these buildings could not be completed until 1942, the CWS expanded as it had in World War I, by seeking assistance from university laboratories.

In Cambridge, the Massachusetts Institute of Technology erected a new building which the CWS leased as a development laboratory.[26] The loca-

[25] Rpt, Maj Gen Harry L. Gilchrist, title: The Chemical Warfare Service, prepared by direction of General MacArthur, 24 Mar 31.

[26] (1) Sylvester John Hemleben, Massachusetts Institute of Technology Chemical Warfare Service Development Laboratory, in the monograph series History of Research and Development of the CWS in WW II. (2) Capt. Jacquard H. Rothschild, "New Development Laboratory Opens," *Chemical Warfare Bulletin* 28 (January 1942), 52–54.

CONFERENCE ON EXPANSION PROGRAM, *Office of Chemical Warfare Chief, January 1942. From left: Brig. Gen. Paul X. English, Brig. Gen. Rollo C. Ditto, Maj. Gen. William N. Porter, Chief of Chemical Warfare Service, Brig. Gen. Ray L. Avery, Col. Augustin M. Prentiss, Maj. William M. Creasy, and Maj. Lester W. Hurd.*

tion was advantageous because it was in the center of an industrial and university area, and because the MIT faculty was at hand for consultation. Operations began in June 1941, under the direction of Capt. Jacquard H. Rothschild. For four years CWS scientists worked here, carrying out a wide variety of investigations. In the course of their assignments the men studied the pilot plant production of phosgene, mustard gas, and thionyl chloride; designed a filling plant for irritant grenades; drew up plans for the M2 field laboratory; assisted with the development of civilian, assault, and headwound gas masks, and collective protectors; investigated flame throwers and flame thrower fuels; and examined German, Japanese, and Italian protective equipment and gas detectors. The laboratory continued to operate until the end of the war when the CWS disposed of its equipment and turned the building back to MIT.

In New York City, Columbia University permitted the CWS to occupy laboratories in the Building of Mines early in 1942.[27] At that time

[27] Capt. Bernard Baum, Columbia University Chemical Warfare Service Laboratories, in monograph series History of Research and Development of the CWS in WW II.

the service was working top speed on the development and production of incendiary bombs, and scientists, under Lt. Col. Ralph H. Talmage, sought to improve magnesium bombs and incendiary fillings. Later in 1942 the Columbia laboratory expanded its operations. The staff investigated the manufacture of napalm, sought substitutes for the scarce components of incendiary gels, and designed stronger base plates for the chemical mortar. The CWS remained at Columbia for twenty months, and then transferred its workers to Edgewood Arsenal where space was available in new laboratories.

As with laboratory space, the CWS found itself in need of larger testing and proving grounds. Since 1921, when the CWS had given up Lakehurst Proving Ground, all testing and proofing had been done at Edgewood Arsenal. The fields there, shared by the Chemical Warfare Board, the Chemical Warfare School, and Ordnance Department's Aberdeen Proving Ground, were overcrowded, close to thickly populated areas, and too small to permit large-scale assessment of toxic agents.

In addition to the laboratory facilities in the United States the CWS had field laboratories in operation overseas. The chemical laboratory companies and laboratory sections of chemical service companies, whose mission was the surveillance of CWS matériel and examination of enemy agents and equipment, were initially supplied with a field laboratory designated as model M1, standardized in 1936 and in service until the latter part of 1943. Its 21,000 pounds of equipment, comprising 88 footlockers, 20 boxes, and 15 crates of laboratory materials, as well as a truck-mounted machine shop, had to be transported on seven 1½-ton trucks. Edgewood manufactured eleven M1 laboratories before the model was discarded in 1943.

In 1942 the CWS issued five trailer vans to the First Chemical Laboratory Company which installed its laboratory equipment in them. The company found that the vans lacked sufficient interior space for the work, they were unwieldly to transport on railroads, they were difficult to conceal from enemy observation in the field, and they were hard to handle on poor roads. After several months the service dropped the idea of putting field laboratories on wheels.[28]

Late in 1942 the development of a more compact laboratory unit, with new and improved materials, was turned over to the National Defense Research Committee (NDRC), the CWS Development Laboratory at

[28] Hilbert Sloan, Field Laboratories, vol. 13 of History of Research and Development of the CWS in WW II.

MIT, and the Technical Division at Edgewood. The new unit, standardized in April 1944 as the M2 base laboratory, and, like the M1, designed for semipermanent installation, was contained in 36 plywood shipping cases and 19 crates, totaling 20,000 pounds, which could be transported in five 2½-ton trucks. Among many improvements in techniques and equipment devised for this unit was a semimicroanalytical system developed by C. S. Nieman and E. H. Swift of the California Institute of Technology.[29]

In December 1943 the CWS began design of still another laboratory, this time a highly mobile unit for proposed laboratory teams accompanying task forces in the combat zone. This portable unit for gas intelligence missions weighed 3,293 pounds and was packed in 7 plywood boxes and 9 smaller cases that could be stowed in a single 2½-ton truck. It was assembled and standardized in October 1944 as the M3 mobile laboratory.[30]

The first new proving ground was set up in 1942 in the desert wasteland of Utah, and included part of Dugway Valley.[31] Dugway Proving Ground became the major installation for the field testing, proof firing, and surveillance of chemical agents and munitions under temperate zone conditions. Here researchers carried out airplane spray tests of unthickened and thickened mustard at various altitudes to develop the technique of air-spraying; to determine the effect of the height and speed of the plane, as well as meteorological conditions of the atmosphere, upon the spray; and to evaluate agents and apparatus. Planes dropped incendiaries on facsimile German and Japanese buildings to enable investigators to learn what happened when bombs of certain types struck enemy structures.[32] They also dropped phosgene, cyanogen chloride, and hydrogen cyanide bombs ranging in size from 100 to 4,000 pounds from different altitudes under different meteorological conditions to test bombs and to estimate the quantity of munitions required to lay down a lethal concentration of gas upon a given area. Researchers determined firing tables for the 4.2-inch chemical mortar and for chemical rockets. They studied the behavior of gas and smoke clouds under different meteorological conditions. Smoke munitions

[29] (1) CWTC Item 1024, Standardization of Laboratory, Base, CWS, M2, 5 May 44. (2) The work of NDRC contract groups at MIT, Cornell, Iowa, Nebraska, and elsewhere is described in W. A. Noyes, Jr., editor *Chemistry, A History of the Chemistry Components of The National Defense Research Committee, 1940–1946* (Boston: Little, Brown and Company, 1948), pp. 174–75, 221–23.

[30] CWTC Item 1198, Standardization of Laboratory, Mobile, CWS, M3, 26 Oct 44.

[31] Bernard Baum, Dugway Proving Ground, in monograph series History of Research and Development of the CWS in World War II.

[32] Noyes, *Chemistry,* pp. 392–94.

DUGWAY PROVING GROUND, UTAH, *major installation for field testing, prooffiring, and surveillance of chemical agents and munitions under temperate zone conditions.*

were fired to permit a comparison of the effectiveness of different munitions, and to ascertain the relative merits of white phosphorus and plasticized white phosphorus. In 1945 the installation was the scene of a most unusual test, the SPHINX project, by means of which the CWS demonstrated to General Staff officers the potentialities of gas munitions against Japanese cave fortifications of the type that had proved invulnerable to high explosives at Iwo Jima.

As the battle lines shifted from North Africa across the Mediterranean, Dugway Proving Ground sent a mobile unit to conduct studies of chemical agents in the Targhee National Forest, and the National Defense Research Committee sent a group from the University of California to Mount Shasta, where the climate and terrain were similar to those in sections of Italy. The investigations of these two groups were chiefly concerned with clouds of nonpersistent gas released from 100-pound M47A2 bombs.

To learn the behavior of agents under Pacific island conditions, Dugway sent other units to Camp Paraiso in the Panama Canal Zone and to Bushnell, Fla. The Bushnell installation, staffed by CWS and NDRC personnel, began operations in November 1943, and continued to function

after the war.[33] The initial test project determined the offensive value of bombs filled with nonpersistent agents when used on semitropical terrain. Later operations ascertained the offensive value of persistent agents in such country, this being a departure from the old tactical concept that persistent agents were a weapon for defense. Between 1943 and the end of the war investigators evaluated a large variety of chemical munitions (bombs, shells, thermal generators, land mines, rocket heads, and spray tanks) for their efficiency in dispersing toxic agents. On Florida beaches they determined the hazard of mustard contaminated sand to assault troops. At the end of the war Bushnell closed its agent and munition program and turned to the testing of insecticides, fungicides, and miticides.

In addition to Dugway Proving Ground and its branches, the CWS established an experimental station in 1944 on San José Island, off the west coast of Panama.[34] Here the CWS, the NDRC, Great Britain, and Canada co-operated in assessing chemical warfare weapons under tropical conditions. Technicians tested a variety of munitions including 1000-pound AN-M79 bombs containing phosgene and cyanogen chloride, and 115-pound M70 mustard filled bombs. They also studied diverse problems such as the hazards faced by troops in mustard contaminated jungle, the purification of water contaminated by chemical agents, and the effectiveness of bangalore torpedoes in clearing paths through mustard spotted vegetation. These studies gave the participants valuable data on the offensive and defensive phases of chemical warfare in jungle fighting.

Assistance from Industries and Universities

The new laboratories at Edgewood, at the Massachusetts Institute of Technology, and at Columbia University, coupled with the new proving grounds at Dugway, Bushnell, and San José, gave the CWS facilities for the tremendous wartime program, but the first installations could not be ready until 1941. To obtain assistance in getting the work started sooner the CWS again went outside of the Army.

Early in 1940 the CWS decided to engage industrial and educational institutions to carry out research and development along certain lines. The

[33] The section on the Bushnell installation is based on Historical Monograph on CWS Experimental Station at Bushnell, Fla. MS in Hist. Off.

[34] (1) Capt. Jay S. Stockhardt, "San José Project," *Armed Forces Chemical Journal*, II (January 1948), 32–35. (2) Col. Robert D. McLeod, Jr., "In the Wake of the Golden Galleon, or Selecting a Jungle Proving Ground," *Armed Forces Chemical Journal* IX (March–April 1955), 36–39.

service, finding that the War Department did not have a contract to cover this type of endeavor, took standard supply contracts, modified them in each case to suit the circumstances, and had them approved by the Office of the Judge Advocate General before signing. The CWS was a pioneer within the War Department in drawing up research and development contracts, and it had to proceed cautiously to keep within regulations. Its experience was subsequently of value to other branches of the Army.

The contracts specified the work that was to be done, but they did not try to tell the contractor how to carry out his task. Each contract included a clause granting the government rights to any invention made as a result of the work. Each contract was written for a fixed sum. In cases where the time stated in the contract proved insufficient to carry out the work, the CWS negotiated a supplemental agreement extending the time and granting additional funds.

From July 1940 to September 1945 the CWS spent nearly five and one-half million dollars for work done under approximately four hundred contracts. At the same time it was receiving a similar kind of assistance indirectly through the efforts of a powerful civilian organization, the NDRC.

The NDRC was established by order of the Council of National Defense on 27 June 1940 to undertake those scientific problems for which the facilities of the Army and Navy were inadequate.[35] In the new organization there were five divisions. Division B (Bombs, Fuels, Gases, Chemical Problems), with James B. Conant as chairman, was responsible for chemical warfare projects.[36] To Division B the CWS recommended the following six projects:

CWS-1. Aerosols—Their Generation, Stabilization, and Precipitation.
CWS-2. Study of the Theory of Toxicity—To Correlate Chemical Structure, Physical Properties and Toxicological Action of Organic Compounds.
CWS-3. Synthesis of Organic Arsenicals.
CWS-4. General Method of Synthesis of Certain Non-Arsenical Organic Compounds Including Several Specific Compounds.
CWS-5. Test of Pro-Knock Materials for Use Against Gasoline Engines.
CWS-6. Chemical Detection of Persistent Chemical Agents.

In December 1940, the CWS added three additional projects:

CWS-7. Fundamental Study of Gas Mask Absorbents.
CWS-8. The Generation of Colored Smokes.
CWS-9. Manufacturing Process for Lewisite.

[35] The History of the NDRC, from the viewpoint of organization, may be found in Irvin Stewart, *Organizing Scientific Research For War, the Administrative History of the Office of Scientific Research and Development* (Boston: Little, Brown and Company, 1948).

[36] An account of the work done for the CWS by the NDRC may be found in Noyes, *Chemistry*.

A tenth project, "Flame Throwers—Fuel Composition and Nozzle Design," was added in February 1941.

On 28 June 1941, the Office of Scientific Research and Development (OSRD) was set up in the President's Office for Emergency Management and the NDRC was transferred to the new agency. In December 1942 the NDRC was reorganized and its alphabetical divisions were broken down into nineteen numerical divisions. Division 9, "Chemistry"; Division 10, "Absorbents and Aerosols"; and Division 11, "Chemical Engineering" directed the majority of chemical warfare investigations.

In undertaking these projects the NDRC drew up the program, selected a contractor (either an academic institution or an industrial firm), and then came to terms with the contractor concerning the scope of the work, patent rights, and the cost. When an agreement was reached, the contractor and the NDRC drew up a detailed plan for research. Officials of the NDRC known as technical aides followed the work of specific contracts. The contractor submitted reports periodically to the NDRC and the CWS showing the progress and results of the project.

The CWS and NDRC maintained liaison through one or more CWS officers from 1941 onward, reinforced by NDRC members in the Office of the Chief and at Edgewood Arsenal from 1942 onward. By August 1942 the volume of university-industrial assistance had reached the point where the CWS and NDRC had to form a joint Technical Committee to plan and allocate all research and development carried out by military and nonmilitary groups. On this committee were the chief of the Technical Division, the director of the Office of Assistant Chief for Matériel, the chairman of the NDRC, and the chairmen of Divisions 9 and 10, NDRC. The chief of the Medical Division joined the committee in August 1943.

By the end of the war the following projects had been added to the CWS list:

CWS-11. Incendiary Leaves.
CWS-12. Thickening of Vesicants.
CWS-13. Prevention of Corrosion of Chemical Munitions, Vesicant Filled.
CWS-14. Analysis and Detection of Chemical Warfare Agents in Water.
CWS-15. Filter Materials.
CWS-16. Filter Design.
CWS-17. Production and Stabilization of Fog.
CWS-18. Effect of Noise on Man and Devices for Producing Such Noises.
CWS-19. Influence Fuzes for Airplane Spray Apparatus.
CWS-20. Biological Problems.
CWS-21. Incendiary Materials.
CWS-22. Rocket Propulsion of Chemical Munitions.
CWS-23. Formation of Flexible Films.

CWS-24. Development of Protective Clothing.
CWS-26. Meteorology.
CWS-27. New Munitions for Chemical Agents.
CWS-28. Acoustical Properties of Gas Masks and Diaphragm Materials.
CWS-29. Non-Volatile Toxic Chemicals and their Uses.
CWS-30. Improvement of the Exterior Ballistics of Liquid-Filled Shell.
CWS-31. Insecticides, Rodenticides and Repellents.
CWS-32. Improvement of 4.2-Inch Mortar

These aspects of chemical warfare were not alone in receiving assistance from civilian organizations; medical research also benefited. In October 1940 the Subcommittee on Clinical Research of the Committee on Medicine, NRC, took up problems dealing with the treatment of mustard-induced bronchopneumonia, the purification of contaminated water, and the treatment of skin lesions caused by vesicant agents. In August 1941, at the request of the Chief of the Medical Research Division, CWS, the Division of Medical Sciences of the National Research Council organized the Committee on the Treatment of Gas Casualties (CTGC).[37] This was a medical advisory body to the Chemical Warfare Service, to assist in organizational problems of medical research and to gather and co-ordinate information on problems and research results obtained in the study of medical aspects of gas warfare in the various OSRD agencies and in the chemical warfare centers of other nations. To the end of the war the CTGC proved of signal help to the Chemical Warfare Service in its acquisition of medical personnel to staff the Edgewood laboratories and in advising on the research conducted there and, under contract, in universities, hospitals, and industrial laboratories.[38] Among the problems investigated was therapy for injuries to the nervous system, for mustard burns, for lung injuries, and for eye injuries caused by vesicant agents.

At the same time the NRC was having this research done for the Medical Research Division of the CWS, the NDRC was sponsoring research on behalf of the toxicological research group. After General Porter merged the medical and toxicological groups into a single Medical Division in July 1943, the new division received assistance from both NRC and NDRC.

[37] Rexmond C. Cochrane, Medical Research in Chemical Warfare, in monograph series, History of Research and Development of the Chemical Warfare Service in World War II, p. 117.

[38] (1) Cochrane, Medical Research in Chemical Warfare, pp. 90–93. (2) A list of the major CMR contracts with their subjects and investigators appears in E. C. Andrus, *et al.*, eds., "Science in World War II," *Advances in Military Medicine*, Vol. II (Boston: Little, Brown and Company, 1946), 870–71. Hereafter cited as *Advances in Military Medicine*, II. (3) The range of OSRD investigations in a single study, on the mechanism of action of war gases, is indicated in Noyes, *Chemistry*, pp. 249–51.

The aforementioned civilian agencies, and the universities and companies that worked for the CWS under contract, rendered invaluable service to the CWS in World War II on all phases of the research and development program. Among their most notable contributions were the M69 incendiary bomb, the M1 mechanical smoke generator, and napalm. The NDRC toxicity laboratory at the University of Chicago screened many hundreds of potential chemical warfare agents, the majority of which had been synthesized in university laboratories under NDRC contracts. Meteorological studies by scientists gave the CWS accurate data on the behavior of gas clouds. Academic and industrial laboratories helped the CWS overcome the undesirable properties of certain standard toxic agents and to improve the large-scale processes of preparing agents. Much of the development of the 4.2-inch recoilless chemical mortar was carried on at the NDRC Allegany Ballistics Laboratory. Investigations on protective ointments led to the new M5 ointment. This list could be extended to a much greater length, but as it stands it serves to show the quality, variety, and magnitude of assistance that the CWS received from nonmilitary organizations.

Co-operation with the British Commonwealth

Shortly before the United States entered the war, the Americans and British began to exchange information on chemical warfare through the U.S. Assistant Military Attaché in London and representatives of the British Purchasing Commission in America. After American forces arrived in the British Isles in 1942, CWS personnel could visit British installations and learn at first hand what the British were doing.

To link the chemical warfare organizations of Canada and the United States, a joint U.S.-Canadian Advisory Committee was established. Membership of the committee was subsequently broadened to include Great Britain. This three-power committee eliminated much duplication of effort, established uniform test procedures, and accelerated co-operative work on such items as toxic gases, flame throwers, and smoke munitions.

In the fall of 1942, the Combined Chiefs of Staff set up the United States Chemical Warfare Committee (USCWC), headed by the Chief, CWS, to co-ordinate all chemical warfare activities.[39] One of the objectives of the USCWC was to insure that all types of chemical warfare matériel used by the British and Americans would be interchangeable. The

[39] Brophy and Fisher, *Organizing for War,* ch. IV.

necessity for this decision is illustrated by a problem involving incendiary bombs. American munitions were attached to the plane by two lugs, British bombs by only one lug. In order to make the bombs suitable for carrying in both American and British planes, the designs had to be changed to provide for three lugs.

Although the principle of interchangeability was of great importance it could not be fully achieved. By the time the United States entered the war, facilities had already been designed to produce models developed for the American Army without thought of standardization with the British. With protective equipment it was practically impossible to obtain a wide range of uniform items. One case where the goal was achieved was that of the British light respirator, whose screw thread was made to take either the British or American canister. In the case of colored smoke there was some uniformity in regard to colors, but no standardization of munitions. There was practically no uniformity of flame throwers or flame thrower fuel, but a standard method of testing was adopted.

Evaluation of United Kingdom and American equipment was accomplished more readily than interchangeability. In April 1944 the Advisory Committee on the Effectiveness of Chemical Warfare Matériel in the Tropics, consisting of representatives of the CWS, the Canadian Field Experimental Station, and the British Army, was established to provide operational data for planning chemical warfare in the tropical theaters of war. This committee was served by the Project Co-ordination Staff which evaluated chemical warfare tests carried out in the United States, Great Britain, Canada, Australia, and India. The staff considered all factors involved in the use of chemical weapons, including weather and terrain, protective devices, and weapons and munitions.

British information, most helpful to the CWS early in the war, continued to the end of the conflict, and covered practically all areas in which the CWS worked. The flow of information, however, was not one-way. The CWS returned the favor by sending reports of weapons, agents, and research across the Atlantic to give the British Commonwealth the benefit of American experience.

Information from the Enemy

Throughout the 1920's and early 1930's the CWS had kept informed of foreign chemical warfare technical activities through reports from chemical officers traveling abroad, and through representatives in the offices of

the military attachés at the London and Berlin embassies. There was no special intelligence unit in the service to handle these matters, and reports from abroad were routed to the appropriate division in the Office of the Chief.[40] Several years before World War II the practice of stationing representatives abroad was discontinued, and the CWS was cut off from any direct contact with European sources. In 1940 the chief established an Information Division to collect, evaluate, and distribute information on enemy chemical warfare activities.[41] This division channeled appropriate data to the technical agencies.

Certain reports received through intelligence caused the CWS to emphasize research along certain specific lines. This was the case with nitrogen mustards which the service had dropped many years before, but which it again began to investigate after learning that the Germans were interested in these compounds. Generally speaking, intelligence reports were not as fruitful as direct examination of captured enemy equipment.

The CWS put its first intelligence units into the field in February 1944 when the Director of Intelligence, ASF, authorized the Chief, CWS, to send teams consisting of one major and four enlisted men to ETO, MTO, Central Pacific Area, South Pacific Area, Southwest Pacific Area, and CBI, where they would compose the CWS Section of the ASF Enemy Equipment Intelligence Service Teams. These teams were trained to examine captured equipment and report any information of value. Before the war was over the original 6 teams were reinforced by 5 more, 1 for the China theater and 4 for ETO.

In addition to its organized procedures for peering over the enemy's shoulder, the CWS at times obtained information directly from officers and men on the fighting fronts. In February 1942, for example, American forces on Bataan, Philippine Islands, captured two flame throwers.[42] Col. Stuart A. Hamilton, Chemical Officer, USAFFE, shipped one of these back to Edgewood Arsenal where the technical staff examined the weapon and adopted the cartridge type of ignition for the American flame thrower.

[40] Many of the intelligence reports on foreign research and development are in the Technical Library, Army Chemical Center, Md.

[41] (1) OC CWS Off O 6, 6 July 40. The Information Division underwent several reorganizations and changes in name. (2) This discussion of CWS intelligence activities is drawn largely from History of Intelligence Activities, OC CWS, 6 July 1940–31 December 1945. CWS 314.7 Intelligence File.

[42] Col. Stuart A. Hamilton, Activities Chemical Warfare Service, Philippine Islands, World War II, 22 Nov 46. In OCMH. (2) Ltr, Hamilton to ACofS, G–2, USAFFE, 21 Feb 42, sub: Report of Physical Examination of Japanese Flame Thrower No. 1, with 1 report and 3 inds. CWS 319.7A/33.

Toward the end of the war in Europe, and after V-E Day, the CWS continued to obtain information on German chemical warfare through two agencies.[43] The first of these was a group known as the Combined Intelligence Objectives Subcommittee (CIOS), organized to uncover all German military secrets and scientific discoveries. The second was the United States' world-wide organization, Field Intelligence Army, Technical (FIAT).

The work of these agencies was done by teams of experts who went into an area after it was overrun. One team of experts spent four months in Germany studying plants that had produced hydrogen peroxide as a propellant for torpedoes and V-2 bombs. Their 350-page report, later released to the public, was the most complete authority anywhere on the manufacture and handling of concentrated hydrogen peroxide. Another team inspected chlorine plants to study the operation of mercury cells, with which the Germans had replaced the diaphragm type cells. Other investigators found plants that had been constructed to synthesize acetylene from hydrocarbons, and to react acetylene under high pressure, processes in which the German chemical industry had been pioneers. The survey of German plants occupied the time of scores of men and produced mountains of reports. This information was released to the public, and proved a stimulant to industry, the profession, and the universities.

While the CWS obtained a large volume of information on German, Italian, and Japanese gas masks, incendiary bombs, smoke munitions, flame throwers, and other equipment from intelligence sources or the examination of captured weapons, the information generally resulted in only minor changes in components of CWS items, rather than in drastic redesign. Information from the British and the NDRC had much more influence in bringing about significant improvements or innovations in matériel.

The new laboratories, proving grounds, testing stations, and sources of friendly and enemy data, gave the CWS a larger technical organization than it ever dreamed of in the 1920's and 1930's. With the additional facilities, funds, and personnel it had the task of sending scientists and engineers along a variety of paths and of producing an extremely diversified line of items. Some of its research was fruitful, some was fruitless. Some of its products were welcomed by fighting men, some were not satisfactory. Like other services that carried on research and development, the CWS had scientific victories and defeats.

[43] Col. Harry A. Kuhn, "German Technical Information," *Armed Forces Chemical Journal*, I (January 1947), 12–14.

CHAPTER III

Toxic Agents

The Chemical Warfare Service came into existence because the armed forces needed a branch to deal with the problems arising from the use of poison gas, and although the service acquired the responsibility for other areas of warfare, such as incendiaries and smokes, its major concern during World War II remained the research, production, and neutralization of toxic agents. The first chemical used in World War I was chlorine, a heavy green gas. As the war progressed liquid and solid compounds were also used to launch chemical attacks.[1]

One of the first steps by the CWS just before World War II was to expand research on the classes of substances that might be suitable for toxic agents. In this program the National Defense Research Committee did much work.[2] Soon after the committee came into existence in 1940, the CWS submitted to it six projects, four of which were concerned wholly or partially with toxic agents. To screen compounds synthesized by hundreds of chemists in universities and industry, the NDRC established in April 1941 a toxicity laboratory at the University of Chicago.[3] In its four years of existence this laboratory screened about seventeen hundred compounds.[4] The most promising of these, including sulphur fluorides,

[1] (1) Despite the inexactness of referring to all these substances as poison "gases," the term has continued to be commonly used. The correct military expression is "toxic agent." (2) Chlorine was not used as a toxic agent in World War II, but was used for other purposes. See ch. XII below.

[2] (1) Noyes, *Chemistry*, pp. 157–62, 166–74. (2) *Chemical Warfare Agents, and Related Chemical Problems*, Summary Technical Report of Division 9, National Defense Research Committee (Washington, 1946), pp. 3–264.

[3] (1) Final Technical Report of the University of Chicago Toxicity Laboratory. OSRD 5527. (2) George H. Mangun, "Toxicity Laboratory, University of Chicago," *Armed Forces Chemical Journal*, I (January 1947), 25–26, 49–50.

[4] The results from the toxicity laboratory occupied fifty-three classified reports. A list of the reports may be found in OSRD 5527.

nitrogen mustards, arsenicals, sulphur mustards, aromatic carbamates, fluoroacetates, and aliphatic nitrosocarbamates were studied in more detail by the CWS at the Edgewood laboratories.

Of the vast number of compounds investigated, the CWS and NDRC found not one new standard agent. The difficulty lay in finding substances that met a large number of varying conditions. The compound had to be highly toxic so that a small amount would contaminate a large area. It had to be available in large quantities from the chemical industry, or it had to be of such a nature that it could be synthesized on a large scale at a reasonable price. It had to be stable during storage and not decompose into harmless materials. It was desirable that the density of the gas or vapor be heavier than air so that the compound would linger over the target. The vapor had to be nonflammable so that it would not be ignited by the flash of the burster.[5] It could not react unduly with air or moisture. It could not corrode the container or evolve a gas that might burst the container. If it were a liquid, the freezing point had to be low, else it would freeze in a cold climate or in airplanes at high altitudes. Finally, the chemical, physical (i.e., color) and physiological (i.e., odor) properties had to be such that the enemy would be unable to detect the gas quickly and would have difficulty in providing protection.

These conditions were difficult to meet. Of the thousands of compounds considered by the CWS between 1917 and 1940, and by the CWS and NDRC during World War II, not one was found that could come up to the standbys of World War I. This was also the experience of Great Britain and the other Allied nations; and only the Germans through an accidental industrial discovery made while investigating insecticides, came upon a new group of agents, the so-called nerve gases or G-agents.[6]

In addition to seeking new agents the CWS spent much time improving the methods of preparing the standard agents and of overcoming such undesirable properties in the agents as instability. The service erected new plants using the improved processes at CWS arsenals and at other locations, and renovated older plants. It advanced the design of

[5] See above, p. 18, n. 54.

[6] In 1936 Dr. Gerhard Schrader, a research chemist with I. G. Farbenindustrie in Leverkusen, synthesized an extremely toxic compound, "Tabun," while investigating insecticides. The compound was reported to the Ministry of War. In 1938 research along the same lines led to "Sarin." "Soman" was prepared in 1944. For the sake of secrecy the Germans called these compounds Trilon, the name of a detergent manufactured in Germany. The existence of the G-agents was unknown to Great Britain and the United States until German chemical shells were captured and analyzed in 1945, although vague hints about them appeared occasionally in intelligence reports from 1943 onward.

chemical munitions, and obtained considerable information on their potential usefulness through exhaustive field tests. Arsenals and depots conducted large-scale surveillance tests to determine the storage life of agents. During World War II the CWS devoted most of the time spent on the research and development of toxics to the standard agents.

Phosgene

Phosgene, or carbonyl chloride (CWS symbol, CG), is a colorless liquid, slightly denser than water. It boils at 47° F. and hence in warm weather is in the form of vapor, unless under slight pressure as in a cylinder or shell. The vapor dissipates into the air in a few minutes, and for this reason CG is known as a nonpersistent agent. The vapor smells like green corn or new mown hay, and is extremely toxic. When inhaled, phosgene damages the capillaries in the lungs, allowing watery fluid to seep into the air cells. If the quantity inhaled is less than the lethal dose the injury is slight, the fluid is reabsorbed, the cell walls heal, and the patient eventually recovers; but if a large amount is inhaled, the air cells become flooded and the patient dies from lack of oxygen. It is difficult to estimate the severity of poisoning since the full effect is usually not apparent until three or four hours after exposure.

Phosgene was the second major agent to appear in World War I. The Germans first employed it in a cloud gas attack against the British in Flanders in December 1915 when 88 tons of the gas released from 4,000 cylinders caused more than 1,000 casualties.[7] The Allies quickly adopted it and used it in enormous quantities throughout the war. It was an extremely dangerous agent, causing more than 80 percent of all chemical fatalities. After the war the CWS surveyed all of the nonpersistent agents, but could not find any that were more effective than phosgene.[8] In 1928 the service classified CG as a substitute standard agent and in 1936 as a standard.[9]

In World War I Edgewood Arsenal and several chemical companies

[7] Lt. Col. Augustin M. Prentiss, *Chemicals in War: A Treatise on Chemical Warfare* (New York: McGraw-Hill, 1937), pp. 154–55.

[8] G. S. Armstrong and S. A. White, Selection of Quick Acting Non-persistent Agent. EATR 191, 4 Apr 35.

[9] (1) Ltr, C CWS to TAG, 21 Feb 28, sub: Adoption of Type (Chemical Agents), and Inds. Copy in CWTC. (2) Memo, C CWS for Chairman, CWS Branch Comm, 26 Feb 36, sub: Classification of Chemical Agents. Copy in CWTC. (3) Memo, C CWS for TAG, 5 Mar 37, sub: Subcommittee Report on Military Characteristics and Classification of Gas, Non-persistent. Copy in CWTC.

produced phosgene for the AEF.[10] The compound was prepared by combining chlorine and carbon monoxide in the presence of a catalyst. There were two methods of carrying out the reaction; in one concentrated carbon monoxide was used, in the other, dilute. The American plants adopted the concentrated gas process, but after the war the CWS weighed the relative merits of the two processes and concluded that the dilute gas method was more practical because it required simpler equipment that would be more readily available in an emergency.[11] The CWS, however, was unable to construct a dilute gas plant because of lack of funds.

From 1922 onward the phosgene plant at Edgewood lay idle as the War Department forbade the manufacture of toxic agents. In 1937 the CWS rehabilitated and operated the plant for a brief period to produce phosgene and to provide the Technical Division with engineering data for a larger plant. The design was ready in 1939, and the new plant constructed and placed in operation in July 1941.[12]

Between 1940 and 1945 the CWS studied the manufacture of phosgene along four lines: improvement of the Edgewood process, pilot plant studies of the dilute gas process, erection of a by-product plant in Tennessee, and investigation of the diphosgene process.

Improvement of the Edgewood plant began in 1942 when the Technical Division carried out experiments that increased the efficiency of the process at an annual savings of $65,000.[13] In 1944 the division established a pilot plant for further improvement of the process.[14] The plant at Edgewood served as model for a plant of thirty tons' capacity a day that the CWS erected at the Huntsville Arsenal and began operating in 1944.[15]

The concentrated gas process used at the Edgewood plant required solid carbon dioxide, pure oxygen, refrigeration equipment, and gas compressors, all classified as critical materials. In July 1942 the CWS Develop-

[10] (1) Short account of the manufacture of L_3 (Phosgene) as carried on at Edgewood Arsenal during the summer and fall of 1918. EAL 572, 1 Dec 18. (2) Historical information concerning the Bound Brook Plant of Edgewood Arsenal. CWS, H-193. (3) Clarence J. West, Phosgene, Chemical Warfare Monographs, vol. 22, pt. 1, May 1919.

[11] L. Vickroy, Post War Developments in the Manufacture of Phosgene. EACD 110, 28 Feb 22.

[12] (1) Brooks F. Smith, Phosgene Plant Design; Operation of Edgewood Arsenal Plant, June, July and August 1937. EATR 267, 25 May 39. (2) N. M. Bouder, Phosgene Plant Design, Final Report on Project A 3.1-1.1. EATR 294, 23 Jun 39. (3) Edgewood Arsenal in Chemical Warfare Production, July 1940-December 1943, pp. 51-53.

[13] Agents II (Lung Irritants), monograph MS, vol. 2 of series History of Research and Development of the CWS (1 July 1940-31 December 1945), pp. 33-35. Hereafter cited as Agents II.

[14] Capt Charles B. Griffen, Jr., and Capt P. H. Schneider, CG Process Development. TDMR 952, 30 Jan 45.

[15] History of Huntsville Arsenal, July 1941 to August 1945, vol. I, pp. 456-65.

ment Laboratory at MIT began to investigate a dilute gas process using ordinary producer gas, containing from 15 to 20 percent carbon monoxide, in place of concentrated carbon monoxide. After eight months of labor the laboratory perfected a pilot plant capable of producing ten pounds of liquid phosgene an hour. Using the data obtained from the trials the laboratory drew up plans for a plant having a capacity of twenty-five tons a day and requiring for the most part standard industrial equipment. The CWS found it unnecessary to construct a dilute gas plant, but the plans were on hand for use in an emergency.[16]

In 1944 the CWS added yet another process. It erected a plant near Columbia, Tenn., to take advantage of the tremendous quantity of carbon monoxide available as a by-product from the Monsanto Chemical Co. phosphate works. This carbon monoxide contained impurities, particularly phosphorus and sulphur compounds, which had to be removed before the gas could be used. The Monsanto Co., under CWS contract, set up two pilot plants for the development of a large-scale method of purifying carbon monoxide and manufacturing phosgene. These pilot plants and those at Edgewood furnished the CWS with information for the design of a large plant with capacity of thirty-six tons a day. Construction began in May 1944, and the first phosgene was produced in February of the following year. Monsanto operated the process until the CWS closed the plant in April.[17]

The fourth and most unusual method of producing phosgene was based on the use of trichloromethyl chloroformate or diphosgene. This compound is less volatile than phosgene and is therefore less dangerous and troublesome to load into bombs and shells. By means of a catalyst it is quickly converted into phosgene. Taking these facts into consideration the CWS conceived the possibility of filling munitions with diphosgene and enclosing a catalyst which would convert the material into phosgene. In 1942 Morris S. Kharasch at the University of Chicago and in 1943 S. Temple at E. I. du Pont de Nemours & Co. investigated the reaction under NDRC contracts. Kharasch also studied the catalysts.[18] The scheme

[16] (1) Hemleben, CWS–MIT Development Laboratory, pp. 34–44. (2) R. P. Whitney, F. W. Holt, Jr., C. H. King, Jr., A Pilot Plant Investigation of the Manufacture of Liquid Phosgene. MITMR 37, 13 Aug 43.

[17] History of the Duck River CWS Plant, *passim.*

[18] (1) M. S. Kharasch. The Preparation of Diphosgene. OSRD 504, 15 Apr 42. (2) S. Temple, Preparation of Diphosgene. OSRD 1437, 20 May 43. (3) M. S. Kharasch, The Catalytic Conversion of Diphosgene into Phosgene. OSRD 332, 9 Jan 42. (4) M. S. Kharasch. Catalytic Conversion of Diphosgene into Phosgene within Closed Heavy Metal Containers. OSRD 899, 28 Sep 42.

appeared practicable, but the CWS finally decided that the advantages of the method did not compensate for the higher cost of diphosgene and the changes that would have been necessary in the design of munitions.

During the war the CWS manufactured and purchased from industry more than forty million pounds of phosgene for use in various munitions.[19] Two munitions for phosgene, the chemical mortar shell and the portable cylinder, had descended from World War I. In the event of gas warfare, the mortar would have been the chief weapon of the ground forces for laying down concentrations of phosgene on caves, dugouts, bunkers, and artillery and machine gun emplacements. From 1941 to 1944 the CWS filled almost half a million 4.2-inch mortar shells with CG. Each shell held almost seven pounds of CG, about 25 percent of the total weight of the filled munition.

The cylinder had been a standard weapon in the static trench warfare of World War I, but it was scarcely suited for the blitz tactics of World War II. It could have been used, however, to overcome resistance within caves or bunkers on Japanese-held islands. It contained thirty-one pounds of phosgene, about 56 percent of the total weight. The cylinder also held about two pounds of carbon dioxide to expel the phosgene in the form of a mist. In view of the possible employment of cylinders, the service retained the final model M1A2, standardized in 1936, until World War II was over.[20]

New phosgene weapons were the 7.5-inch rocket, the AN–M78 500-pound bomb, and the AN–M79 1000-pound bomb. The rocket, which was the World War II counterpart of the World War I Livens projectile, was readied by 1944. The Navy took almost eight thousand of these, the Army more than twenty-three thousand.

Development of phosgene bombs started in early 1942 when the CWS asked the Ordnance Department for a series of chemical bombs of approximately the same shape as general purpose bombs. The new munitions were produced in 1943 and sent to Dugway Proving Ground for testing and evaluation.[21] The 1000-pound bomb holding 415 pounds of CG

[19] Richard H. Crawford, Lindsley F. Cook, and Theodore E. Whiting, Statistics, "Procurement," p. 21. Copy in OCMH. Statistics is a forthcoming volume in the series UNITED STATES ARMY IN WORLD WAR II.

[20] (1) CWTC Item 1545, Obsoletion of Cylinders, Portable, Chemical, M1, M1A1, M1A2, and Apparatus, Charging, Portable Chemical Cylinder, M1, 28 Mar 46. (2) CWTC Item 1614, same title, 23 May 46.

[21] (1) Baum, Dugway Proving Ground, pp. 201–24. (2) CWTC Item 826, Classification of Fillings for Chemical Munitions, 15 Oct 43. (3) CWTC Item 881, Classification of Fillings for Chemical Munitions, 3 Dec 43.

turned out to be an extremely effective munition. When it hit the ground and burst open a large amount of liquid phosgene was freed. The evaporating liquid cooled the vapor and caused it to flatten out against the ground in a pancake-shaped cloud instead of rising as had been expected. This cloud always formed, regardless of the weather. The 500-pound bomb containing 205 pounds of CG was not quite half as effective as the 1000-pound bomb, but it was still a useful munition because American planes could carry more than twice as many 500-pound bombs as 1000-pound bombs. The CWS filled twenty-five thousand 500-pound bombs in 1944, and sixty-three thousand 1000-pound bombs from 1943 to 1945. The Air Forces could, in case of chemical warfare, have used these chemical bombs against targets beyond mortar range, against fortifications on Iwo Jima and other islands before amphibious assaults were made, and against strategic targets, such as war plants during working hours.

After the war examination of stocks of gas weapons captured in Germany showed that the German Army had on hand thousands of 250- and 500-kilogram phosgene bombs.[22] These bombs, however, had been largely superseded by bombs containing the nerve gas tabun, which the Germans began producing in 1942.[23] The Germans did not favor the use of phosgene in shells. Italy had phosgene bombs, and shells ranging in size from 149-mm. to 305-mm.[24] Phosgene shells, from 75-mm. up to 150-mm. were captured from the Japanese, who also had bombs in sizes up to 200 kilograms.[25]

Had gas warfare started early in World War II, phosgene would probably have been used widely by the Allied and the Axis armies wherever the tactical situation called for the employment of a nonpersistent, delayed-action agent. Sometime in 1942 or thereafter, evidence indicates that as a stockpile accumulated the Germans would have introduced tabun, and phosgene would then have had to share the field with the new nerve gas.

Hydrogen Cyanide

At the battle of the Somme in July 1916 French artillery fired shells filled with hydrogen cyanide (CWS symbol, AC).[26] The compound had

[22] *First United States Army, Report of Operations 23 Feb–8 May 1945, Annex No. 9,* p. 192.

[23] Intel Div, CWS, Theater Service Forces, ETOUSA, German Chemical Warfare, World War II, Sep 45, p. 39. Hereafter cited as German Chemical Warfare.

[24] CW Intel Bull No. 16, Italian Chemical Warfare, 1 Jul 43.

[25] (1) CW Intel Bull No. 49, pt. I, Japanese Gas Shells, 1 Feb 45. (2) CW Intel Bull No. 14, Aerial Gas Weapons of Germany, Italy and Japan, 15 May 43.

[26] Hydrogen cyanide is also known as hydrocyanic acid and prussic acid.

been familiar to chemists for a century but this was the first time it was used in warfare.[27] It is a colorless liquid which evaporates quickly at room temperature and boils at 78° F. The liquid and vapor interfere with normal processes in body cells, particularly in the respiratory center of the nervous system, and if present in more than a certain small concentration quickly causes death. But if cyanide is present in less than the lethal concentration the cells can convert it into a harmless compound and the body is uninjured. In this respect AC is different from phosgene, mustard, and other toxic agents which are harmful even when present in less than the lethal dose.

The French had some difficulty in using hydrogen cyanide as an agent because AC vapor is light and therefore has a tendency to diffuse instead of lying close to the ground. Also, AC has a tendency to decompose—sometimes so violently that the container exploded.[28]

In an attempt to cut down the rate of diffusion the French mixed AC with stannic chloride. To prevent AC from decomposing the French added arsenic trichloride. To keep the mixture from crystallizing and to make soldiers more susceptible to the agent they added chloroform. The addition of these compounds diluted the AC so much that the final mixture contained only 50 percent of the cyanide. This meant that twice as many shells, or shells with twice the capacity, were needed to deliver the same weight of the cyanide—a rather wasteful procedure.

In addition to employing a dilute agent the French used small shells holding only about a pound of filling. Furthermore, their artillery fired at a slow rate. As a result the French were not able to place a lethal concentration of gas on an enemy area. Other nations observed the apparent failure of hydrogen cyanide and came to the conclusion that it was not suitable as a war gas, but the French never lost faith in it and continued to use it until the end of the war.

Despite its drawbacks, hydrogen cyanide was inexpensive, commercially available, and had several of the other properties that have been mentioned as being necessary or desirable for a toxic agent. After the war the opinion gained ground in the CWS that the agent had not been given a fair trial.[29] In the 1930's chemists made laboratory and field studies, in-

[27] Maj. Gen. C. H. Foulkes, *"Gas!" The Story of the Special Brigade* (Edinburgh: William Blackwood & Sons, 1934), p. 108, says that hydrogen cyanide was "reported" to have been employed by Austrian artillery in Italy in September 1915.

[28] After World War I the CWS experienced several explosions among AC shells and cylinders in storage sheds at Edgewood Arsenal.

[29] Rudolph Macy, Hydrocyanic Acid: Its Military History and a Summary of its Properties. EATR 219, 20 May 37.

cluding firing tests with 155-mm. howitzer shells, and came to the conclusion that the compound was potentially an effective lethal, nonpersistent agent.[30] They overcame the old problem of decomposition with the aid of Du Pont and American Cyanamid, manufacturers of hydrogen cyanide, who gave information which finally enabled the CWS to stabilize the cyanide in munitions.[31]

After the United States entered World War II the CWS extended its work and tested AC bombs of the 100-, 115-, 1000-, and 2000-pound size. The 1000-pound bomb, holding approximately 200 pounds of agent, proved particularly suitable as a munition. With this large quantity of the cyanide the cooling effect brought about by evaporation of the liquid produced a cloud of gas whose density was greater than air and which hovered close to the ground. Under favorable meteorological conditions the cloud was fatal hundreds of yards from the point of impact.[32]

The bomb was unquestionably an efficient munition for use in a cyanide gas attack, but the tests uncovered a serious problem. The vapor which billowed outward from the bomb was easily ignited by the flash of the burster. In some tests, practically all the bombs caught fire as they split open. There were three ways of preventing the burning of AC: one was to devise a "cold" bursting charge that would not ignite the vapor, the second was to use a more powerful bursting charge that would push the vapor cloud away from the bomb faster than the flame could follow, and the third was to add a substance that would make AC more difficult to ignite. Since the first two methods would have required too much time and field work, the third was followed. Anton B. Burg and his associates conducted the research under an NDRC contract at the University of Southern California. They discovered that hydrocarbons such as those in gasoline were the best flame inhibitors. Dugway Proving Ground tested AC protected with hydrocarbons and found that it did not take fire as readily as pure AC, but bombs still burned occasionally, and the problem was never completely solved.[33]

The 1000-pound bomb would have been the chief means of dumping hydrogen cyanide on the enemy if gas had been used in the latter part of the war. It was standardized for use with AC in 1943, and about 5,000

[30] Samuel A. White, Hydrocyanic Acid: Field Tests (Static and Artillery Fire) of HCN in 155-mm. Shell. EATR 299, 5 May 39.

[31] G. N. Jarman, HCN: Stability in Shell, Status Report, 1940. EATR 340, 6 Mar 41.

[32] Baum, Dugway Proving Ground, pp. 214–29.

[33] *Military Problems with Aerosols and Nonpersistent Gases.* Summary Technical Report of Division 10, National Defense Research Committee (Washington, 1946).

bombs were filled and stored.[34] This munition accounted for almost all of the 1,132,000 pounds of AC procured by the CWS from July 1940 to the end of 1945.[35]

An unusual AC weapon was a glass bottle holding about a pint of liquid.[36] This grenade was produced from 1942 onward as a possible last-ditch weapon against tanks or in overcoming bunkers. It was finally dropped from the approved munitions in 1944 because of the danger of breakage during shipment, either through accident or enemy action, and because tests had proven that it would not always break on soft jungle underbrush or if it glanced off log bunkers.[37]

In view of the fact that the Germans did not regard hydrogen cyanide as highly as some other agents, they did not procure large quantities or fill shells, bombs, or grenades. They did, however, think that AC might be useful in the form of a spray, and the Luftwaffe carried out extensive field trials with aerial spray tanks.

The Japanese, on the other hand, felt as the Americans did about the value of AC, but they planned to use it in shells and grenades rather than in bombs. Their AC munitions ranged from mortar shells—light, medium, and heavy—to 150-mm. howitzer shells. Japanese glass grenades containing hydrogen cyanide were captured on Guadalcanal, in Burma, and on the upper Chindwin River.

Hydrogen cyanide was not as important as some of the other toxic agents, but if gas warfare had broken out, both sides would certainly have employed it in tactical situations where its rapid action and lack of persistence would have been of advantage to the attacking force.

Cyanogen Chloride

Cyanogen chloride (CWS symbol, CK) is a colorless liquid slightly denser than water.[38] It boils at a temperature of 55° F., giving off a vapor which is approximately twice as dense as air and which irritates the eyes

[34] (1) CWTC Item 826. (2) CWTC Item 881. (3) Chemical Warfare Service Report of Production, 1 Jan 40 through 31 Dec 45, p. 4. Prepared by Prod Br, Proc Div, CWS. CWS 314.7 Procurement File.

[35] Consolidated Chemical Commodity Report, 16 Oct 51, p. 16. This report was prepared by Facilities Br, Ind Div, OC CmlO. CWS 314.7 Procurement File.

[36] CWTC Item 495, Standardization of HCN Filling for Grenade, Frangible M1, 10 Feb 42.

[37] (1) CWTC Item 1117, Obsoletion of Grenade, Frangible (AC), M1 and Grenade, Frangible (FS), M1, 31 Aug 44. (2) CWTC Item 1201, same title, 26 Oct 44.

[38] In June 1943 the CWS changed the symbol CK to CC. But the letters CC resembled CG (phosgene) when printed, and there was some confusion. In November 1944 the symbol CK was restored. See CWTC Item 1179.

and nasal passages. When air containing a high concentration of the vapor is inhaled the compound quickly paralyzes the nervous system and causes death. When a low concentration is inhaled the reaction is not so rapid, but the compound accumulates in the body until a lethal concentration is reached.

Cyanogen chloride was first used as a toxic agent by the French in October 1916. In 1917 and 1918 the CWS investigated the manufacture, the chemical, physical, and physiological properties, and the effectiveness in shells and Livens projectiles of cyanogen chloride.[39] The Research Division found that the gas passed rapidly through the German but not through the American mask. This was an important discovery and might have led to the adoption of the compound as an American chemical warfare agent had not the density of the vapor been so low that the CWS felt it was impossible to place a lethal concentration of cyanogen chloride on enemy positions.[40] The same decision, apparently, was also reached by the French and other European armies, for cyanogen chloride was never used to any extent.

Between the wars the CWS conducted few trials with CK. The compound's chief test came in 1933 when the Technical Division, searching for an agent that would act more rapidly than phosgene, the standard nonpersistent agent, examined CK and decided it was not acceptable.[41] But early in World War II the CWS, while examining captured Japanese and German masks, obtained data that indicated that CK would penetrate enemy canisters in harassing concentrations if the humidity of the air was high—a condition common to the tropics.[42] This discovery opened the way for the adoption of CK as a standard agent. As a prelude to standardization technicians had to learn if a lethal concentration could be laid down over enemy positions, to see if CK was available in quantities sufficient for military use, to find means of overcoming the instability of the compound, and to modify the canister of the mask for greater protection to American soldiers.

The CWS and NDRC assessed CK at Dugway Proving Ground in

[39] Clarence J. West, Cyanogen Derivatives, Chloride, Bromide, Iodide, Sulfide, Chemical Warfare Monographs, vol. 25, April 1919.

[40] Phosgene, mustard, lewisite, and other agents have a density 3.4 to 7 times that of air. CK is only twice as dense as air. Only one agent, hydrogen cyanide, is less dense than CK.

[41] Armstrong and White, Selection of Quick-Acting Nonpersistent Agent.

[42] A comparison of enemy and friendly canisters may be found in: (1) CWTC Item 811, Standardization of Nonpersistent Agent, Cyanogen Chloride, 3 Sep 43. (2) *Military Problems with Aerosols and Nonpersistent Gases*, Summary Technical Report of Division 10, National Defense Research Committee (Washington, 1946).

February and March 1943.[43] Testers placed a 100-pound chemical bomb containing 67 pounds of CK and a 500-pound bomb containing 280 pounds of CK in shallow craters and split them open with tetryl bursters. They estimated the strength of the gas cloud by means of vapor sampling devices and goats placed downwind from the burst. The trials showed that the 500-pound bomb released a low-hanging cloud that was lethal for a considerable distance and that the flash from a tetryl burster would not ignite the compound.

Even though CK was shown to be suitable as an agent, the CWS still might not have standardized it if the protective properties of the American mask had not been improved. The mask carried by soldiers at the start of the war gave excellent protection against chloropicrin, phosgene, mustard, and lewisite but only fair protection against hydrogen cyanide, and cyanogen chloride. The CWS in 1943 adopted Type ASC charcoal, treated with chromium, which was more effective in removing CK. Thus at the time when the investigators were uncovering evidence of the usefulness of CK on the offense, the technicians were developing better protection for defense.

Another hurdle that remained was the chemical instability of cyanogen chloride which had a tendency to polymerize. That is, the short molecules of the compound would join together spontaneously to form large molecules of a new compound. Sometimes the reaction took place so rapidly that the container exploded. Polymerization within bombs or shells also meant a wastage of the munition, since the new compounds were relatively harmless as agents.

The task of preventing or retarding polymerization was undertaken by Division 10 of the NDRC in 1942. A group of chemists headed by Wendell M. Latimer of the University of California made a preliminary search for stabilizing compounds. Later researchers of American Cyanamid Co., working under CWS contract, took up the quest and uncovered additional information. Dugway Proving Ground contributed to these studies by setting up a large-scale surveillance test of munitions filled with CK. In August 1943 the NDRC started an additional experimental program under Anton B. Burg of the University of Southern California. Burg's group ran nearly two thousand tests on cyanogen chloride. This work expanded the knowledge of the chemistry of CK, particularly the reactions which took place during storage, but still did not provide the complete

[43] B. G. Macintire, Static Tests of CC in 100-lb. and 500-lb. Chemical Bombs. DPGMR 5, 12 Mar 43.

answer. In 1944 Division 9 of the NDRC entered the field with a group of men under Kharasch of the University of Chicago. This group observed the retarding power of inorganic compounds on the polymerization of CK and finally found that a small amount of sodium pyrophosphate would preserve CK under normal storage conditions for many years. From then on sodium pyrophosphate was used to stabilize CK.

In order to obtain sufficient CK for chemical munitions, the CWS had to erect a plant. Before the war the only plant in the country was owned by the American Cyanamid Co. at Warners, N.Y. This plant produced sufficient cyanogen chloride for industry, but could not turn out the large quantity needed for chemical warfare. In October 1943 the War Department approved the construction of a CWS plant with a capacity of fifteen tons, later increased to sixty tons, per day.[44] The Chemical Construction Co. broke ground for the "Owl" plant, as it was called, on 27 November at a site adjacent to the American Cyanamid Co.'s hydrogen cyanide plant at Azusa, Calif. This location thus assured the "Owl" plant with the hydrogen cyanide needed in the process. American Cyanamid, which operated the plant under contract, started the first unit in April 1944.

The CWS chose two types of munitions for cyanogen chloride—4.2-inch mortar shells and bombs. The mortar shell was made the official CK munition for ground forces in 1945, but was not filled. Instead, almost all of the twenty-five million pounds of CK procured by the CWS went into 33,347 M78 500-pound bombs, each holding 165 pounds of agent, and 55,851 M79 1000-pound bombs, each holding 332 pounds.[45]

Cyanogen chloride bombs, in event of chemical warfare, would probably have been used early against the Japanese, particularly in the tropics, where the humidity would have assisted the vapor in passing through the canister. The soldier then would have been forced to tear off his mask, exposing himself to other lethal agents dropped simultaneously. In time the Japanese and Germans could have treated the charcoal in such a way that CK would no longer pass through their canisters. The agent would then have lost its chief usefulness as a war gas.

Mustard Gas

In World War I the protection experts on each side tried to devise means of neutralizing enemy agents as soon as new agents appeared. Chlo-

[44] History of the Owl Plant, *passim.*

[45] Consolidated Chemical Commodity Report, p. 56. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 4.

rine, the first gas used, was soon parried by an adequate mask. As new gases appeared, the masks were improved. Soon the mask furnished full protection and men were gassed only when they were careless, panicky, or caught by surprise. But in July 1917 the German Army brought out a new type of agent, mustard gas, that not only attacked the respiratory system but also the skin, soaking through clothes and shoes and raising painful blisters. It was almost impossible to shield soldiers completely against mustard. It became the king of battle gases and caused four hundred thousand casualties before the armistice.[46]

Crude mustard gas (CWS symbol, H) was a mixture of approximately 70 percent β,β'-dichloroethyl sulfide and 30 percent of sulphur and other sulphur compounds. It was an oily, brown liquid that evaporated slowly, giving off a vapor five times heavier than air. It was almost odorless in ordinary field concentrations but smelled like garlic or mustard in high concentrations—hence the name. It irritated and poisoned body cells, but generally several hours passed before symptoms appeared.

The chief problem concerning mustard had to do with its purification. In World War I the CWS adopted the Levinstein process of the English in which ethylene reacted with sulphur monochloride under carefully controlled conditions.[47] The reaction at first glance seems simple, but actually it was rather complex and defied the efforts of CWS chemists to chart its course. The impurities were of such a nature that they could not be isolated and analyzed. They resisted separation from the main ingredient, β,β'-dichloroethyl sulfide, and caused or hastened decomposition of the sulfide. Decomposition was a disadvantage, first, because some of the resulting products corroded the storage container, making storage unsafe; secondly, other products settled out as a sludge that could change the ballistic properties of shells or prevent the liquid from dispersing in the most favorable pattern; thirdly, a gas was evolved which built up pressure and threatened to burst containers; and, later, after airplane spray tanks were devised, the decomposition products made it impossible to thicken mustard for use in airplane spray attacks.

Chemists of the research and development division investigated methods of purifying mustard, but the processes proved to be impractical for large-scale use.[48] After the armistice the CWS disposed of the mustard

[46] Prentiss, *Chemicals in War,* p. 199.

[47] James K. Senior, "The Manufacture of Mustard Gas in World War I," *Armed Forces Chemical Journal,* XII (Sept–Oct 1958), 12–14, 16–17, 29; XII (Nov–Dec 1958), 26–29.

[48] Clarence J. West, Dichloroethyl Sulfide and Homologues, Chemical Warfare Monographs, vol. 40, 1 Aug 18.

plants at Cleveland, Ohio, Buffalo, N.Y., Midland, Mich., and Hastings-on-Hudson, N.Y., and closed the plant at Edgewood. Research on mustard practically ceased until the early 1930's when the plant at Edgewood was restored. In 1937 this plant was put into production for a two-week period but not until 1940 was it opened for large-scale production.[49]

After Edgewood Arsenal began producing mustard again the CWS, assisted by the NDRC, examined a number of purification methods including distillation under low pressure, distillation using steam and organic liquids, extraction with solvents, treatment with ammonia, flash distillation, and crystal fractionation. Of these processes only vacuum distillation, steam distillation, and solvent extraction proved to be feasible for use on a large scale.

Purification by extraction dated back to 1918 when the CWS carried out laboratory and pilot plant investigations to see if β,β'-dichloroethyl sulfide could be separated from impurities by dissolving it in gasoline or other solvents. The insoluble impurities remained in the residue and the sulfide was recovered from the solvent by distillation.[50] In 1942 this line of research was resumed at the CWS–MIT Development Laboratory. The chemists first obtained data on the solubility of the constituents of crude mustard in various solvents, and on rates of solution. Then, using glass extraction apparatus, they determined the data necessary for designing a large-scale extractor.[51] The NDRC assisted by awarding a contract to the Texas Co. for pilot plant studies. Texas Co. engineers proved that large-scale extraction was practical, but they found that the product was less pure than steam distilled mustard and that the process required complex, expensive equipment.

Steam distillation, in which a current of steam was passed into the still to help carry away mustard, leaving the impurities behind as a tarry residue, had also been tested by the CWS back in 1918. In 1943 the CWS–MIT Development Laboratory re-examined this method and found that it produced a sulfide of high purity and fair stability, and that only simple equipment was required.[52] The Texas Co. then made a pilot plant inves-

[49] (1) Capt William Creasy and L. Wilson Greene, Six-Ton Levinstein HS Plant, Engineering Test. EATR 254, 14 Apr 39. (2) Edgewood Arsenal in Chemical Warfare Production, pp. 48–51.

[50] (1) Single, Successive and Continuous Extraction of Mustard Gas with Solvents. EAL 11, 24 May 18. (2) Thomas G. Thompson and Harry Odeen, "The Solubility of β, β'-Dichloroethyl Sulfide in Petroleum Hydrocarbons and Its Purification by Extraction with These Solvents," *Industrial and Engineering Chemistry,* 12 (1920), 1057–62.

[51] Scott W. Walker, Capt John H. Carpenter, and Theodore Q. Eliot, Purification of Levinstein H. MITMR 66, 23 May 44.

[52] *Ibid.*

tigation to obtain data for the construction and operation of a full size plant.[53] It is possible that this process would have been the one utilized, as it seemed the most promising at the time, had not the CWS and NDRC come across a superior method, vacuum distillation.

The CWS obtained the clue which led them to vacuum distillation in November 1943 when Capt. J. W. Eastes visited the University of Illinois to confer with NDRC chemists. He learned that they had distilled at low pressure mustard which had been washed with water, and that the temperatures in the distillation column indicated that fairly pure β,β'-dichloroethyl sulfide could be prepared in this way.[54] In other words, water removed certain impurities, and distillation removed the remainder. The CWS had investigated vacuum distillation earlier, but had never washed the crude mustard before distilling.[55] The Technical Division investigated the process and found that it produced a purer and more stable β,β'-dichloroethyl sulfide than the other methods and that it was quite practical so far as apparatus was concerned. A pilot plant was first set up and then a full-scale plant.[56] In 1945 the service switched to the new process at Edgewood and at Rocky Mountain Arsenal.[57] By the end of the year 9,218,357 pounds of distilled mustard (symbol, HD) had been produced. With the successful production of HD, production of the old Levinstein mustard was halted.

Mustard, in terms of the quantity that the CWS stockpiled, was the most important American toxic agent. The plants at the Edgewood, Huntsville, Pine Bluff, and Rocky Mountain arsenals produced 174,610,000 pounds, exclusive of the nine million pounds of the new distilled mustard.[58]

Since mustard evaporated slowly and thus remained effective from several hours to several days, depending upon the weather and terrain, its use was indicated on strategic targets or on enemy positions that would not be taken immediately by American troops. Thus, it could be used to "seal off" an enemy area into which American troops were advancing, and

[53] W. E. Kuhn, G. B. Arnold, and L. E. Rudisch, Purification of Levinstein Mustard. OSRD 3217, 5 Feb 44.

[54] Agents III (Vesicants), monograph MS, vol. 3 of series History of Research and Development of the CWS (1 July 1940–31 December 1945), pp. 80–81.

[55] Elford D. Streeter, "Continuous Vacuum Still for 'Mustard Gas,'" *Industrial and Engineering Chemistry*, 11 (1919), 292–94.

[56] Capt William R. Wheeler, Capt Willard Marcy, Andrew E. Perry, and William R. Wilson, Vacuum Distillation of Levinstein H, Pilot Plant Study. TDMR 985, 17 Mar 45.

[57] History of Rocky Mountain Arsenal, 1945, vol. III, pt. I, pp. 647–715.

[58] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

to hamper enemy lines of communication, airfields, landing beaches, artillery emplacements, and observation points. In withdrawals it could be used to contaminate the routes of enemy advance.

For delivery of mustard by ground troops the CWS had 4.2-inch mortar shells, artillery shells, and land mines. The land mines were simply rectangular 1-gallon tin cans, such as were commonly used to hold varnish or syrup. They had a capacity of ten pounds of mustard. When exploded with a slow-burning fuze or by electrical means, the mines spread mustard over a considerable area. They were intended for use as booby traps or in contaminating fields, roads, and buildings. The CWS procured and stored (but did not fill) almost two million such mines.[59] For possible use by troops, 540,746 4.2-inch mortar shells were filled and stored. For the artillery, 1,360,338 75-mm. Mk 64, 1,983,945 105-mm. M60, 784,836 155-mm. Mk 2A1, 290,810 155-mm. M110, and smaller quantities of other shells, were readied.[60]

For carrying out aerial mustard attacks the CWS had chemical bombs and spray tanks.[61] The service procured 594,216 M70 and M70A1 115-pound bombs, developed by the Ordnance Department, and 539,727 M47A1 and M47A2 100-pound bombs, developed by the CWS in the 1930's.[62] The bombs were slightly over 4 feet long, about 8 inches in diameter, and contained a cylindrical burster. The bombs held from 60 to 70 pounds of mustard, and when dropped contaminated an area of from 15 to 40 yards in diameter, depending upon the altitude of the plane, hardness of the ground, thickness of vegetation, and so on.[63]

In addition to bombs the service procured 92,337 M10 30-gallon airplane spray tanks. A plane flying at an altitude of 100 feet and carrying four of these tanks could spray mustard over an area 75 to 80 yards wide and 600 to 700 yards long. A larger tank, the M33 or M33A1, of which the service obtained 20,598, held more than twice as much mustard. A plane carrying two of these tanks could contaminate an area 75 to 100 yards wide and 700 yards long.[64]

In anticipation of the use of spray tanks the CWS expended much effort in trying to improve the spraying properties of mustard. In the 1930's the CWS had accepted the doctrine that mustard spray attacks would be

[59] *Ibid.*, p. 24.
[60] CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 28–30.
[61] Spray tanks were also used to dispense liquid smoke agents. See ch. IX, "Smoke."
[62] CWS Rpt of Production, 1 Jan 40 through 31 Dec 45, pp. 3–4.
[63] FM 3–6, Employment and Characteristics of Air Chemical Munitions, Oct 46.
[64] *Ibid.*

carried out by planes flying at low altitudes and moderate speeds. By 1941 plans called for planes flying a mile high and at speeds up to 350 miles an hour. At high altitudes and speeds the wind could easily carry small droplets beyond the target or spread them over too wide an area. Small droplets also evaporated so quickly that they either might not reach the ground at all, or else become so minute as to be practically ineffective. To obtain the desired large droplets chemists began to search for materials which would thicken mustard.[65]

After starting the project CWS learned that the British had already determined the best size for high altitude droplets and were adding various substances to mustard to increase the particle size. In co-operation with the NDRC the CWS tested more than seventy thickeners.[66] Finally, the search narrowed down to polystyrene and methyl methacrylate. After methyl methacrylate sheet scrap (Plexiglas and Lucite) became available from aircraft factories, the CWS adopted it as a mustard thickener.[67]

As things turned out the work of the CWS and NDRC on thickeners went for naught. High and low altitude spray tests carried out by the CWS in co-operation with the Signal Corps and Army Air Forces at Dugway Proving Ground from 1943 onward finally proved that unthickened mustard was a better substance for spraying purposes than thickened mustard, and thickening agents were given up.[68]

Like the American Army, the German Army placed much reliance on mustard. An examination of captured documents and gas dumps showed that they had produced more than twice as much mustard as any other agent for use in artillery shells of all calibers, mortar shells, 250- and 500-kilogram bombs, rockets, and spray tanks.[69] A notable feature was the tendency to use mustard in conjunction with thickening agents or with substances that would lower the freezing point. Arsenöl, a mixture of arsenic compounds, mainly diphenylchloroarsine, was widely used for this purpose.

The Japanese, too, used mustard as a filling for shells and bombs. They

[65] Agents III (Vesicants), pp. 96–135.

[66] *Miscellaneous Chemical Engineering Problems*, Summary Technical Report of Div 11, National Defense Research Committee (Washington, 1946).

[67] (1) CWTC Item 1007, Standardization of Thickened Persistent Agent, HV, and Persistent Agent Thickener, VV, 5 May 44. (2) CWTC Item 1074, same title, 7 Jul 44.

[68] (1) Baum, Dugway Proving Ground, pp. 153–64. (2) CWTC Item 1277, Obsoletion of HV and VV, 22 May 45. (3) CWTC Item 1346, same title, 24 May 45.

[69] (1) German Chemical Warfare, p. 32. (2) L. Wilson Greene, "Documents Relating to the Capture of a German Gas Dump," *Armed Forces Chemical Journal*, III (January 1949), 26–32.

favored a 50–50 mixture of mustard and lewisite, the lewisite acting to lower the freezing point and also as a toxic agent in its own right.

In all probability if toxics had been called upon in World War II, mustard would have been used extensively whenever tactics pointed to the need of a persistent chemical agent.

Lewisite

In 1918 a group of organic chemists headed by Dr. Winford Lee Lewis prepared a highly vesicant substance, dichloro (2-chlorovinyl) arsine, which they named lewisite.[70] The CWS leased the old Ben Hur Automobile Co. building at Willoughby, Ohio, installed equipment, and began to produce the agent.[71] A shipment was on the seas headed for Europe when the war ended. The CWS kept the existence of lewisite and the site of its manufacture a strict secret during the war, but later revealed the information in scientific journals.[72] After the armistice the service closed down the Willoughby plant and did not prepare the compound again except in laboratory quantities until 1941.

In the early method of manufacture, acetylene and arsenic trichloride were combined with the aid of a catalyst, aluminum chloride. The process was complicated, a large quantity of unwanted by-products were formed, and sometimes the crude product exploded as it was being distilled. In the early 1920's the CWS renewed its research on lewisite, but was unable to continue the investigation to any great length because of the small staff and projects of higher priority.[73] In 1939 the service set out to design a pilot plant that would produce lewisite by a continuous process using the old aluminum chloride catalyst. Shortly thereafter reports from Great Britain told of the successful use of mercuric chloride as a catalyst.[74]

[70] (1) W. Lee Lewis, Summary of Work Done in Organic Unit No. 3, Offense Research Section, CWS, 26 Mar 19. CWS, H-209. (2) Clarence J. West, Organic Arsenic Derivatives, Chemical Warfare Monographs, vol. 21, pt. 4, April 1919. (3) The CWS symbol for lewisite in World War I was G-34. Later it was change to M-1, and finally to L.

[71] The plant is described in *The Story of the Development Division, Chemical Warfare Service* (1920), pp. 213–23, a souvenir book issued by General Electric Co.

[72] (1) W. Lee Lewis and G. A. Perkins, "The Beta-Chlorovinyl-Chloroarsines," *Industrial and Engineering Chemistry,* 15 (1923), 290–95. (2). W. Lee Lewis and H. W. Stiegler, "The Beta-Chlorovinyl-Arsines and their Derivatives," *Journal of the American Chemical Society,* 47 (1925), 2546–56.

[73] (1) G. E. Miller, The Laboratory Development of a Method of the Manufacture of M-1. EACD 239, 5 Jan 23. (2) A. B. Reed, Investigation of New Methods for the Preparation of M-1. EACD 352, 20 Aug 25. (3) H. V. Wright and H. G. Shaffer, Development of Manufacturing Process for M-1. EACD 367, 1 Mar 26.

[74] Production of Lewisite by a New Process, pt. I. Laboratory and Semi-Technical Development, 13 Dec 39, S.O./R/448.

The CWS checked this work, found that the new catalyst was an improvement, and adopted it.[75] But since the mercuric chloride was a batch process, unlike the aluminum chloride process which had been continuous, engineers had to modify the design of the pilot plant.[76] Furthermore, with the new catalyst there was considerable corrosion of equipment.[77] As a result of the problems attending the change in process the production of lewisite was held up until the end of 1942, when plants were opened at Huntsville and Pine Bluff Arsenals.[78] In 1943 a larger plant was started at Rocky Mountain Arsenal.[79]

While the CWS was erecting and starting plants, evidence was accumulating that lewisite might have only limited use. The service had no World War I data to use in evaluating lewisite since the war ended before the agent reached France. The information gained from field tests between 1920 and 1940 was not sufficient for World War II.[80] To obtain additional data the CWS conducted toxicological and field tests.[81] Results indicated that lewisite was of less value than had been supposed because there was difficulty in setting up a high concentration in the field, the gas mask gave complete protection against the vapor, the vapor had a distinctive odor that made it readily recognizable, and the agent could be readily decontaminated. In addition, British chemists had come upon a powerful therapeutic agent, DTH or BAL (British Antilewisite), that destroyed lewisite on contact.[82]

Consideration of all these facts led the CWS to close the lewisite plants in 1943, after 20,000 tons had been produced.[83] Because of the possible utility of lewisite under certain limited conditions, a supply was retained

[75] (1) Capt N. H. Hale, M–1 Process Development, Use of Mercuric Chloride as the Catalyst. TDMR 280, 24 Apr 41. (2) Capt R. M. Cone, M–1 Process Development, Pilot Plant Production of M–1 by a Continuous Process Using Mercuric Chloride as Catalyst. TDMR 354, 6 Mar 42.

[76] M–1 Manufacturing Plant—1941 Design. ETF 112.62–1.

[77] A. M. Reeves and Capt N. H. Hale, M–1 Process Development, Mercuric Chloride Catalytic Process, Corrosion Resistance of Miscellaneous Materials to Mercuric Chloride, Catalyst Solution and Crude M–1. TDMR 326, 21 Nov 41.

[78] (1) History of Huntsville Arsenal, pp. 436–55. (2) Pine Bluff Arsenal, Preliminary History, Sec. VII.

[79] History of Rocky Mountain Arsenal, 1945, vol. III, pt. I, pp. 767–864.

[80] (1) J. E. Mills, H. W. Walker, R. Macy, B. G. Macintire, B. F. Smith, and H. Scheer, Lewisite Field Tests. EACD 411, 28 Feb 31. (2) E. L. Wardell, Lewisite (M–1), 1940 Summary of Physiologic and Toxicologic Data. EATR 285, 15 Mar 41.

[81] (1) Capt Fred E. Culp, Lewisite, Dispersion as Airplane Chemical Spray. TDMR 473, 20 Nov 42. (2) Project Co-ordination Staff, Relative Value of Lewisite, 15 Jun 45. ETF 112.5.

[82] A. L. Stocken and R. H. S. Thompson, The Treatment of Arsenical Burns with Dithiol Compounds, Oxford Univ, Research Item 21, Report 33, 26 Apr 41.

[83] CWS Report of Production, 1 Jan 1940 through 31 Dec 45, p. 20.

throughout the war. Afterwards the CWS sank a large quantity at sea, and finally abandoned the agent completely.[84]

As has been mentioned, lewisite, because of its ability to lower the freezing point of mustard (which was only 58° F.), was used in the form of lewisite-mustard mixtures by the Japanese. The Russians also employed lewisite for this purpose. The Germans were familiar with L–H mixtures for cold weather, but they preferred to use other arsenical liquids in place of lewisite.

Nitrogen Mustards

In 1935 there appeared an article by Kyle Ward, Jr., describing the preparation of a new compound, 2,2′,2″ trichlorotriethylamine, and calling attention to its marked vesicant action.[85] The CWS prepared and studied a sample of the substance, but found that it was less vesicant than mustard.[86] Early in World War II the CWS learned through intelligence that the Germans were working with the same compound and with related compounds—which by now had gained the name of the "Nitrogen Mustards" because of their analogy to mustard gas.[87]

These reports led the CWS, NDRC, and British laboratories to synthesize and test a large number of nitrogen mustards. Three compounds known as HN–1 (N-ethyl(2,2′dichloro)diethylamine), HN–2 (N-methyl-(2,2′dichloro)diethylamine), and HN–3 (2,2′,2″ trichlorotriethylamine) were most promising because of their vesicant action and their lack of odor, and these the CWS studied intensively.

The British concentrated mainly on HN–2 and HN–3, but the Americans felt that HN–1 would be the most useful. Edgewood Arsenal set up a small pilot plant in 1942. Using data obtained from this plant, the CWS in 1943 set up a larger plant at Pine Bluff Arsenal capable of producing one ton per day.

In the meantime field evaluation showed that the 1936 estimate had been correct, and that the nitrogen mustards were not as potent as mustard gas. The plant at Pine Bluff turned out about 100 tons of HN–1 over

[84] CCTC Item 3114, Obsoletion of Lewisite, 2 Nov 55.

[85] Kyle Ward, Jr., "Chlorinated Ethylamines, A New Type of Vesicant," *Journal of the American Chemical Society,* 57 (1935), 914–16.

[86] T. P. Dawson, W. J. H. B. Wells, and C. W. MacFarlan, Preparation and Vesicant Action of Tris(B-chloroethyl)amine and Tris(B-chloroethyl)amine Hydrochloride. EATR 281, 22 Mar 39.

[87] Nellie M. Cone, Possible Chemical Warfare Agents of the Axis Powers. TDMR 616, 26 Apr 1943.

a period of four months, mainly to mislead German intelligence, and then closed down.[88]

The Germans had much more faith in nitrogen mustards than the Americans, and during the war turned out about 2,000 tons of HN-3. At the end of the war they had on hand 105-mm. and 150-mm. artillery shells, and 150-mm. rockets, filled with HN-3.[89]

Chloroacetophenone

Both sides used tear gas early in World War I to harass opposing troops. Troops exposed to tear gas had to wear masks for long periods of time and were very uncomfortable in the old-fashioned, heavy, bulky devices.

During the war the French, Germans, and British introduced a greater variety of tear gases than any other class of agents. After the United States entered the conflict, American chemists investigated chloroacetophenone (CWS symbol, CN) and found that it had the advantage of being cheaper and less corrosive to the inside of shells than other tear gases. The CWS developed methods of producing the agent, but the war ended before large-scale manufacture got underway.

After the armistice the service selected chloroacetophenone as the standard American tear gas. It erected a manufacturing plant at Edgewood Arsenal (1922), and developed a number of munitions for dispersing solid CN or solutions of CN in the field. The solid could be scattered from shells and grenades by means of high explosives, and volatilized from pots and candles by means of heat. Solutions of CN in chloroform (CNC), with chloropicrin in chloroform (CNS), and in carbon tetrachloride and benzene (CNB) could be thrown out by grenades, shells, and high pressure cylinders.

In 1941 the CWS erected a modern plant with a rated capacity of one ton of CN per day. This became the sole CWS plant in 1943 when the old 1922 plant was dismantled.[90] The manufacture of chloroacetophenone involved three steps: the production of monochloroacetic acid, the chlorination of the acid to chloroacetyl chloride, and condensation of chloroacetyl chloride with benzene in the presence of a catalyst. The CWS was aware of another method that was potentially capable of being adapted to large-scale manufacture, the chlorination of acetophenone. If this could be

[88] *Report of Activities of the Technical Division During World War II,* OC CWS, p. 200.
[89] German Chemical Warfare, pp. 32, 126–27.
[90] History of Edgewood Arsenal, pp. 553–54.

done satisfactorily the service was assured of a dependable source of low-cost CN.

In 1944 the Solvoy Process Co. contracted to develop the process and obtain data necessary for construction and operation of a plant. As events turned out the new plant was not needed, but the technical information was at hand in case of an emergency.[91]

In addition to the development work on CN the CWS tested new compounds for their lacrimatory effect. The Universal Oil Products Co. and Du Pont suggested other possibilities. But none of the new tear producing chemicals proved superior to the standard agent.

During the war the CWS produced at Edgewood Arsenal and purchased from the Pennsylvania Salt Manufacturing Co. and the Lake Erie Chemical Co. a total of 1,281,560 pounds of chloroacetophenone.[92] A portion of this went to make up 5,282,000 pounds of CNB tear gas solution, another portion went into 3,309,000 pounds of CNS solution.[93] Almost all of this solution was stored, but some was used to fill 4.2-inch chemical mortar shells, and 75-mm., 105-mm., and 155-mm. artillery shells.

Solid chloroacetophenone went into pots and grenades. The tear gas pot was a modified version of the ordinary tin can and was filled with 1.2 pounds of a CN-powder mixture. When the pot was ignited by a matchhead, heat from the burning powder volatilized the CN. The pot gave off CN smoke for several minutes. Edgewood Arsenal filled a total of 785,383 pots for possible use in the war.[94]

The tear gas grenade was one of the first munitions developed by the CWS after World War I. The body was a small tin can having six holes to let out smoke. The filling contained CN and a powder that provided the heat to volatilize the CN. During World War II, the CWS filled 689,610 M7 grenades, each containing about six-tenths of a pound of tear gas mixture, at the Edgewood and Huntsville Arsenals.[95]

Since the CWS had learned back in the 1920's that tear gas grenades were not enough to drive determined men from their posts, they adopted the practice of adding another agent that would cause vomiting and other reactions. Gradually they perfected a mixture of chloroacetophenone and adamsite (CWS symbol, DM), as a filling for grenades. Adamsite caused

[91] Development of Process For Manufacture of CN, Final, 14 Sep 44. ETF 141.6–10.
[92] Consolidated Chemical Commodity Report, p. 73.
[93] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.
[94] *Ibid.*, p. 23.
[95] *Ibid.*, p. 21.

nausea, pain in the chest, sneezing, coughing, headache, and other disorders. It had another advantage—it acted so rapidly that the victims were unable to pick up the grenades and throw them back, as they did occasionally with ordinary tear gas grenades. Between 1941 and 1944, the Edgewood and Huntsville Arsenals filled 582,327 M6 grenades, each holding about six-tenths of a pound of chloroacetophenone-adamsite mixture.[96]

In 1943 the Provost Marshal General requested the CWS to develop a tear gas grenade with the size, shape, and weight of a baseball for military police to use in breaking up riots. The finished grenade, standardized in February 1945, was a plastic ball holding about two-tenths of a pound of CN, fused to burst 2–3 seconds after it left the hand and before it could be picked up by a rioter and thrown back. The service produced more than 10,000 of these riot grenades by the end of the year.[97]

Tear gas rockets, for possible use as antitank missiles, were first investigated by the CWS in 1942 with assistance from the California Institute of Technology and the National Bureau of Standards. While this work was in progress the Ordnance Department developed and standardized the antitank high explosive rocket, M6. The CWS thereupon turned to the Ordnance rocket and developed heads to carry chemical agents. The antitank tear gas rocket was finally dropped, but the idea took a new turn in 1943 when the Provost Marshal General's office requested a rocket for use, like the tear gas grenade, in controlling riots. The CWS modified the rocket head to meet the new requirements, but the problems associated with ballistics, bursters, and size proved so difficult that in 1944 the project was canceled.

The Germans and Japanese, like the Americans, used CN. The Germans employed it in two forms, one being solid CN, while the other was a mixture of CN, wax, and explosive. The explosive mixture was used in 250-kilogram and 500-kilogram air burst bombs, from which CN was dispersed in lumps.[98] The Japanese had on hand an unusual tear gas candle containing a propellant charge capable of tossing a one-quarter pound chunk of CN a distance of 130 to 300 yards, depending on the angle of elevation. For closer quarters a grenade containing a solution of CN in carbon tetrachloride was available.[99]

In tactics, tear gases would probably not have been as useful in World

[96] *Ibid.*
[97] *Ibid.*
[98] German Chemical Warfare, pp. 130–32.
[99] CW Intel Bull No. 8, Japanese Chemical Warfare Weapons & Equipment, 15 Feb 43.

War II as they were in 1914–18. Positions did not remain static as they had in World War I, and the opportunities for harassment would not have been as great. In certain cases, however, such as attacks upon Japanese caves and bunkers, or upon isolated positions, in the Pacific Islands, the gases might have brought about surrender or have driven the enemy into the open.

Adamsite

The German Army introduced vomiting gases or sternutators into chemical warfare in July 1917, as an ingenious method of penetrating the canisters of Allied gas masks. They first used a solution of diphenylchloroarsine (CWS symbol, DA), which evaporated and left minute particles of DA floating in the air. The canisters at that time were able to trap true gases, the particles of which were molecular in size, but they could not retain the larger particles of DA, which were colloidal in size. Therefore the DA passed through the canister into the mask and was inhaled by the soldier. It irritated his eyes, nostrils, throat, and chest, causing nausea and vomiting. The victim had to tear off his mask, exposing himself to lethal gases fired at the same time.

After the United States entered the war, American chemists investigated the possibility of manufacturing DA. The German process proved to be complicated. Still, the CWS might have gone into production if chemists had not found a related compound that could be manufactured more easily. This was diphenylaminechloroarsine, which was named adamsite after the chemist Roger Adams.

The United States did not produce vomiting gas in time for use by American troops. In the 1920's the CWS operated, for a brief time, a pilot plant for the production of DA and DM at Edgewood Arsenal, but it did not need a full size plant since DM could be purchased from the chemical industry.

The development work, instead, concentrated on means for spreading sternutators in the field. This could be done by explosion, which shattered the agent into a dust or mist, or by heat, which produced smoke. Engineers tested irritant smoke shells, ranging in size from 75-mm. to 105-mm., filled with solid agents and high explosives (HE), or with solutions of agents and HE, up to 1942, but the service did not produce any for combat use. Smoke candles, which were simply cans filled with a mixture of agent and fuel, proved to be much more efficient for dispersing DM. The early candle, dating from 1920–22, was displaced in 1941 by a

new model, M2, which differed in having a better fuel. The M2 weighed 9 pounds, held 2 pounds of DM, and burned from three to five minutes. Edgewood Arsenal filled 92,485 candles during the war, with a portion of the 644,589 pounds of DM purchased by the CWS.[100]

The Germans employed DM as a filling for base ejection and HE shells, candles, and bombs; and DA solution as a filling for rockets.[101] The Japanese relied upon another arsenical vomiting gas, diphenylcyanoarsine (DC), as a filling for mortar shells, artillery shells, and candles.[102]

Undoubtedly vomiting gases would have found much less use in World War II than they had in 1917–18 because the canister of the gas mask had been improved by the addition of filters which held back fine particles. In certain limited situations, such as attacks upon isolated posts or upon surrounded caves or bunkers, the vomiting agents might have been employed to bring about surrender or weaken resistance.

An investigation of the status of chemical warfare within Germany made after V–E Day disclosed that it had produced a total of approximately 78,000 tons of agents—mustard, tabun, arsenöl, chloroacetophenone, phosgene, adamsite, nitrogen mustard, and diphenylchloroarsine—during the Hitlerian period.[103] In addition, the Germans had appreciable stocks of Italian, French, Greek, Polish, Hungarian, and Yugoslavian agents at their disposal. The quantity of war gases produced by Japan was placed at one-tenth of the German production. American production, on the other hand, amounted to more than 146,000 tons of chemicals—mustard, chloroacetophenone, phosgene, adamsite, nitrogen mustard, hydrogen cyanide, cyanogen chloride, and lewisite—from 1940 to the end of 1945.[104]

Although the United States did not employ toxic agents during World War II, the money and time that went into the research, development, field tests, and production was not wasted. The armed forces had supplies of agents and equipment with which they could have waged warfare energetically if necessary. In this sense the work of the CWS was America's insurance against chemical warfare.

[100] (1) Consolidated Chemical Commodity Report, p. 80. (2) CWS Rpt of Production, 1 Jan 40 through 31 Dec 45, p. 5.

[101] German Chemical Warfare, pp. 127–32.

[102] (1) CW Intel Bull No. 8. (2) CW Intel Bull No. 49, pt. I, 1 Feb 45.

[103] German Chemical Warfare, pp. 31–51.

[104] Compiled from Crawford, Cook, and Whiting, Statistics, "Procurement"; CWS Rpt of Production; and Consolidated Chemical Commodity Report.

CHAPTER IV

Protection Against Toxic Agents

"Unfortunately, except for blister gases, there is no practical method of detecting gases other than the sense of smell," wrote Brig. Gen. Alden H. Waitt early in the war.[1] But sensory tests were hazardous and uncertain, particularly for chemicals with little odor or which were masked by the enemy or by field conditions, and the CWS had long sought rapid, foolproof chemical and physical tests.

By March 1942 a number of blister gas detectors, all of which were based on color changes in a dye base and had their origins in British and American developments in 1918, had been standardized. They included the M4 vapor detector kit, capable of registering even faint concentrations of nitrogen and sulphur mustards; M5 liquid vesicant detector paint; M6 liquid vesicant detector paper; and M7 vesicant detector crayon, sensitive to mustard and lewisite.[2] Although the CWS had not discovered a better dye base than that developed by the British, NDRC chemists at the University of Chicago, at the University of Virginia, and at Ohio State improved its composition and developed new detector materials.[3]

An excellent detector kit proved to be the M9, developed with NDRC help in the CWS laboratories at Edgewood and MIT and standardized in July 1943.[4] The Army considered this compact, efficient, and widely used kit one of the significant developments of the CWS defensive research program. Any soldier could learn to operate it after brief training, and it proved itself during the war in the inspection of chemical munitions at U.S. Army depots at home and abroad.

[1] Brig. Gen. Alden H. Waitt, *Gas Warfare* (New York: Duell, Sloan, and Pearce, 1942), p. 205.

[2] CWTC Item 483, Military Characteristics and Standardization of Chemical Agent Detectors, 31 Mar 42.

[3] Noyes, *Chemistry*, pp. 157–62, 166–74.

[4] (1) CWTC Item 783, Standardization of Kit, Chemical Agent Detector, M9, 23 Jul 43. (2) Hemleben, CWS–MIT Development Laboratory, pp. 73–82. The M4 Kit was made obsolete by CWTC Item 1476, 4 Oct 45.

Superior to the M4 vapor detector kit in every respect, the M9 was an adsorption type of detector, consisting of a hand pump and nearly two hundred small tubes of reagent dyes in silica gel, capable of detecting even slight concentrations of such war gases as the mustards, phosgene, and cyanogen chloride.[5] The discovery by Weldon G. Brown at the University of Chicago of a sensitive and specific detector for any war gas reacting to alkali (such as the mustards) was of signal importance in the development of the kit.[6] Tests devised later for lewisite, carbon monoxide, and hydrogen cyanide were at once incorporated in the kit.

After a requirement was established in March 1943, the laboratory at MIT also got up an agent sample collection kit, the MIT-E12, which enabled the user to get samples of airborne agents as well as agents in contaminated soil and to keep them without loss or decomposition until they could be delivered to a field laboratory. This was standardized in August 1945 as the M12 agent sampling kit and, along with a newly developed M10 chemical agent analyzer kit and the M11 smoke identification kit, was made a component of the M3 mobile laboratory unit.[7]

Unknown to the American Army, the Germans had discovered nerve gases, a new class of toxic compounds. The CWS first learned of the existence of these agents after the war was over. None of the reagents in detector kits, nor any other U.S. detector devices, were sufficiently rapid or reliable to warn in time of the presence of nerve gases. In liquid form these agents reacted with the detector paint in the American kit, but no substance in it could detect the agents in spray or vapor form. Had these gases been used it is likely that only the onset of clinical symptoms would have revealed their presence. Despite the accomplishments of the United States in developing sensitive methods of detection, the definite evidence in 1945 that the Germans had nerve gases reopened the whole problem of detection.

As for enemy methods of detection, the Germans had a powder containing a dye which, when sprinkled on liquid mustard, changed color. German vesicant detector cards worked in the same manner as American vesicant detector paper, but were more sensitive to some reagents, and gave a more sharply defined color. For testing the air outside fortifications, the Germans had an apparatus with six pumps, operated electrically or manu-

[5] TM 3-290, 27 Mar 44, pp. 70-78.

[6] Noyes, *Chemistry*, pp. 217-19.

[7] CWTC Item 1407, Standardization of Chemical Warfare Agent Detection and Sampling Kits, 2 Aug 45.

TYPES OF GAS MASKS, APRIL 1918. *From left, American, French, early British, and German.*

ally, which forced air through six tubes of reagents. A German detector kit, comparable to CWS model M9, contained tubes of reagents and a small hand pump to force air through the tubes.[8]

The Japanese also had detector kits, a number of which were captured during the war. One of these, tested at the CWS-MIT laboratory late in 1943, was larger and heavier than the CWS model M9, had no reagent for nitrogen mustard, gave uneven results, and allowed misleading interpretations of tests owing to the faintness of some reactions. On the other hand, a naval-type detector examined shortly thereafter, although also without a test for nitrogen mustard, compared favorably with the M9 in design, simplicity, and effectiveness of operation, and had several good points that were considered for possible inclusion in later American models.[9]

The Gas Mask

Gas masks were the earliest devices for protecting soldiers against toxic agents. The German Army supplied crude masks to the troops who released chlorine at Ypres, the first chemical attack of World War I.

[8] (1) Hemleben, CWS-MIT Development Laboratory, pp. 202–03, 210–12. (2) Intel Div, OC CWS, ETOUSA, German Chemical Warfare Materiel, p. IV–C–1.

[9] (1) Hemleben, CWS-MIT Development Laboratory, pp. 201–04. (2) Off, Ch Cml O, USASOS, Southwest Pacific Area, Japanese Chemical Warfare. Hereafter cited as Japanese Chemical Warfare.

ARMY PHOTOGRAPHER WEARING SERVICE GAS MASK *with M1A2 facepiece, Camp Robinson, Arkansas, January 1942.*

Between 1915 and 1918 the warring nations developed a variety of masks, some completely covering the head and others covering only the face. American troops in France first wore French and British gas masks, then the American C. E. (Corrected English) mask, and finally the R.F.K. box respirator, a modification of the British mask by Ralph R. Richardson, E. L. Flory, and Waldemar Kops of the CWS. The R.F.K. gas mask consisted of a canister, a fabric facepiece with nose clip, mouthpiece, and hosetube, and a carrier for the two units.[10] It provided adequate protection against the agents used on the Western Front, but was uncomfortable if worn for long periods. After the war came the 1919-model gas mask, consisting of a facepiece and hosetube of rubber, covered on one side with elastic stockinette, a canister, and a carrier assembly. The trapezoidal facepiece was fitted with circular eyepieces of laminated flat glass, deflectors to discharge air over the eyepieces to prevent fogging, an outlet valve, an angletube, and a head harness. The canister was of the radical flow type containing a filter unit for the removal of solid and liquid particles from incoming air and charcoal and soda lime absorbents for the disposal of gases. This mask was designated MI-I-I and adopted as standard in 1921. It was supplied in five sizes and with improvements remained the standard U.S. Army gas mask until 1940. After the United States entered World War II, substantial quantities of this service mask, then designated the M1A2-9A1-4, were still available in reserve stocks.[11]

In improving the mask during World War II the CWS sought to

[10] A detailed description of the R.F.K. mask may be found in Fries and West, *Chemical Warfare,* pp. 210–20.

[11] (1) The M1 and its improved versions, the M1A1 (1934) and M1A2 (1935), were not declared obsolete until 1944. CWTC Item 1193, Obsoletion of Stockinette Type Facepieces and Large Size Gas Mask Carrier, 26 Oct 44. (2) The model of a gas mask was designated by the

make it more comfortable, increase the degree of protection, and to make it lighter. One of these steps was to develop a fully molded faceblank. It eliminated the vulnerable chin seam, the angletube, separate deflectors, and multiple metal parts in the eyepiece assembly, and it also brought the lenses of the eyepiece closer to the wearer's eyes, thereby enlarging his field of vision and reducing the dead air space in the facepiece. This molded facepiece also resulted in lower manufacturing costs by permitting mass production methods of assembly, in contrast to the hand work required in the older masks. The new service mask was heavy and not waterproof, but it was an excellent device for protecting the wearer against toxic vapors.

SOLDIER WEARING SERVICE GAS MASK *with M2A2 facepiece during maneuvers, Camp Polk, Louisiana, June 1942.*

Because there was urgent demand for the new fully molded facepieces, the CWS provided only three sizes of molds for its manufacturers.[12] These molds were based on fitting tests on a limited number of workers at Edgewood Arsenal. Variation in the manufacturers' molds made it possible to fit 90 percent of the troops with the so-called universal size, and large and small sizes were provided for special cases. Their wearability was confirmed in tests on more than a thousand soldiers at Camp Edwards, Mass. Difficulties in tooling for the production of these facepieces precluded further changes.

The chief gas mask problem, the CWS felt, was not the faceblank but better absorbents and filters for the canister. The possibility of meeting with new Axis toxic agents and the development of war gases by the United

three "M" numbers of the facepiece, canister, and carrier, respectively. "A" represents an alteration in the basic model design. In models under development, "E" stood for experimental and "R" for revision. (3) A study of World War II masks and their components appears in the S. H. Katz, "Status of the U.S. Army Service Gas Masks," *Armed Forces Chemical Journal,* II (October 1947), pp. 32–40.

[12] They included the Industrial, Dryden, Continental, Sun, Acushnet Process, Firestone, Goodyear, General Tire, and U.S. Rubber Companies.

States made it desirable to find better canister materials. The first attack on the problem was on the absorbents, and NDRC contracts were set up for fundamental studies at the University of Illinois, at Johns Hopkins University, and at Northwestern University.[13]

Whetlerite, a copper impregnated, activated charcoal, was the absorbent then used in the M9A1 canister.[14] Mixed with 20 percent soda lime, this filling removed such standard gases as chloropicrin, phosgene, mustard, and lewisite. It furnished only a fair degree of protection against hydrogen cyanide and cyanogen chloride, a degree thought particularly dangerous in the case of hydrogen cyanide because glass grenades containing this agent had been found among captured Japanese munitions. Initial studies at Northwestern University confirmed the British finding that the addition of silver to the charcoal in the canister greatly improved protection against phosgene and hydrogen cyanide, and the CWS adopted this new composite whetlerite early in 1942.[15] Studies later that year indicated that soda lime, included in the canister since World War I to assist in the adsorption of volatile acid gases such as phosgene and hydrogen cyanide, was no longer needed and it was removed.[16]

The NDRC meanwhile tackled the problem of increasing the cyanogen chloride absorbing power of canisters to meet the possibility that the CWS might adopt this substance as an agent. Research at Northwestern University led to the addition of chromium to the silver and copper already in the charcoal, a measure which considerably improved the cyanogen chloride protection of the canister, even under the severest semitropical weather conditions that could be simulated in the laboratory. The service adopted this third type of charcoal (Type ASC) in July 1943 and incorporated it in the M9A2 canister.[17] Shortly thereafter, scientists developed highly satisfactory wood and coal charcoals as substitutes for the unobtainable coconut charcoal used before the war.[18] As a result, the charcoal and its impregnites in the 1943–44 canister gave the United States an absorbent considered better than those in either the German or Japanese canisters.

[13] NDRC research is reported in Noyes, *Chemistry*, pp. 296–313.

[14] CWTC Item 40, Canister, Service, M1XA1—Standardization, 12 Sep 39.

[15] (1) Lt Col Charles E. Loucks, Visit to Porton Experimental Station. London MA Rpts 41524, 19 Aug 40, p. 1, ETF 550E284. (2) CWTC Item 535, Standardization of Light Weight Service Gas Mask, Military Requirement and Military Characteristics, 4 Aug 42.

[16] The Value of Soda Lime in Gas Adsorbents, OSRD 437, 6 Mar 42.

[17] CWTC Item 772, Standardization of Canister, Service, M9A2, 23 Jul 43.

[18] Saul Hormats, Development of the Impregnated Charcoals for U.S. Military Gas Mask Canisters. TDMR 1201, 13 Feb 46.

The second phase of canister improvement involved filters, incorporated to remove solid toxic particles breathed into the gas mask canister.[19] The filter paper in all canisters in 1940 consisted of a cellulose fiber mat known as alpha web, which had recently been improved by impregnating it with fine carbon particles. This filter assured substantial protection against toxic smokes, such as adamsite, but it increased the resistance to air flow and it offered only limited protection against liquid particles. The development of new mechanical smoke generators necessitated further work on the filter, because fine oil particles of the smoke deteriorated the impregnated paper. Gas mask experts tested rock wool, fiber glass, and other materials as paper substitutes, and finally found that asbestos, a material in British, German, Japanese, and Russian filters, added to the alpha web made the canister safe against minute droplets of oil.[20]

The CWS-MIT Development Laboratory, in co-operation with industrial paper companies and Arthur D. Little, Inc., produced three types of asbestos bearing paper, each of increasing effectiveness. After 1942 they were used successively in place of the carbon-impregnated filter paper in the M9A2 and M10A1 canisters.[21] Further research led to the substitution for the asbestos of a paper fiber made from esparto grass, obtained from Morocco. The new fiber had less air resistance in the canister while it maintained a filtering capacity comparable to asbestos. The service further improved this filter material by treating it with dimethyl silicane, which rendered the paper highly water repellent—a useful property when troops had to ford streams while carrying the gas mask.

The M2 type service mask previously described was, from the point of view of the technical staff of CWS, an excellent product. Anticipating that gas would be used in the war, the service had designed a mask that would provide troops with the most complete protection possible against gas attack. The mask was rugged and efficient, but it was heavy (weighing almost five pounds with its steel box canister), bulky, inconvenient, and therefore unsuited to the combat requirements of World War II. Troops in training in 1940 and 1941 wore the mask unwillingly and only for gas exercises, leaving it behind on combat maneuvers. When the War Depart-

[19] NDRC filter studies of W. H. Rodebush at the University of Illinois and E. P. Stevenson and T. L. Wheeler of Arthur D. Little, Inc., are reported in Noyes, *Chemistry,* pp. 265–72. Those at MIT appear in Hemleben, CWS-MIT Development Laboratory, pp. 120–25, 128–30.

[20] CWTC Item 759.

[21] (1) CWTC Item 772. (2) CWTC Item 827, Standardization of Canister, Service, M10A1, 15 Oct 43.

ment insisted that the mask be worn in all exercises, the ground arms reacted at once. The design had to be changed if troops were to fight effectively while wearing it.[22]

The requirement established in January 1942 for a lighter and less cumbersome mask for combat troops resulted in the development of the lightweight service gas mask. With a smaller, rounded canister, a shorter hose and a simpler carrier, this mask weighed 3½ pounds, yet because of better absorbents and new filter materials, it provided almost the same, though not as prolonged, protection as the heavyweight service mask.[23] One shortcoming of the new mask was the increased breathing resistance, caused principally by the smaller canister. Nevertheless, when Cavalry, Infantry, and Armored Force Boards, as well as Airborne Command tests of the new mask were completed, the Army Ground Forces recommended that the mask be issued as quickly as possible.

The mobility of modern warfare, its jungle operations, and particularly the increase in amphibious operations brought demands from the theater commanders and the Army Ground Forces for an even lighter and more compact gas mask, and especially for one that could be waterproofed. The requirement suggested a snout type mask such as was used by German assault troops. This type would not have an awkward hosetube, would weigh less than two and a half pounds, be waterproof or carried in a waterproof carrier, offer the same protection as the lightweight service mask, and not interfere with the soldier's firing in a prone position.[24]

The problem was turned over to the CWS-MIT Development Laboratory. In a series of tests of experimental models by the 544th Engineers of the 4th Amphibian Brigade in combat exercises at Camp Edwards, it appeared that a cheek-mounted canister gas mask of the type used by the British, rather than a snout type, would provide the least interference with combat activities. Technicians therefore modified the lightweight service mask faceblank by boring a hole in the left cavity and fitting the canister rigidly to the cheek of the blank. A new aluminum M11 canister, adapted from the German design and two-thirds lighter than the previous steel canister, had a water-repellent smoke filter and a wide, deep bed of charcoal. It was much lighter, yet it provided almost as much protection as the lightweight service mask canister. Finally, they made a waterproof car-

[22] Interv, Hist Off with Col George J. B. Fisher, 8 Aug 54.
[23] CWTC Item 587, Standardization of Light Weight Service Gas Mask, 29 Sep 42.
[24] CWTC Item 722, Military Requirement and Military Characteristics for Assault Gas Mask, 11 Jun 43.

SERVICE GAS MASK *with M4 facepiece worn by women in training at Camp Breckinridge, Kentucky.*

rier for the mask from butyl rubber-coated cotton duck. Its multiple folding closure made the entire contents of the carrier watertight. It was later reported that in mishaps during amphibious operations, the bouyancy provided by this carrier saved the lives of a number of soldiers.[25] The assembled units, weighing three pounds, were standardized as the M5-11-7 combat gas mask in July 1944, after production had already started.[26] Over half a million of the combat masks were produced, and this was the mask which was issued to certain assault elements for the invasion of Normandy and which was carried ashore in later amphibious operations.

Among a number of special masks developed before the war was the optical gas mask, standardized in 1939. This mask, originally requested by the Navy and later by AGF for Signal, Coast Artillery, and Antiaircraft personnel using aircraft warning and fire control instruments, contained

[25] Katz, "Status of Army Service Gas Masks," *Armed Forces Chemical Journal,* II (October, 1947), p. 39.

[26] (1) CWTC Item 1093, Standardization of Mask, Gas, Service, Combat, M5-11-7, 7 Jul 44. (2) Further details of the assault mask project appear in Hemleben, CWS-MIT Development Laboratory, pp. 130-53.

small, optically ground lenses for instrument observation and a diaphragm for speech transmission. The poor fit and bulkiness of this mask led to a lighter model designed at the CWS-MIT Laboratory for use by the Coast Artillery and standardized in January 1944. The Chemical Warfare Board found the mask satisfactory, but the Armored Board in a later test did not consider it wholly acceptable and further development was abandoned. As the AGF reported in August 1945, "no existing gas mask is entirely satisfactory for use by armed personnel who are required to employ optical instruments in the performance of their assigned duties." [27]

The diaphragm gas mask was a special mask first designed for the Armored Force and produced in January 1941.[28] By means of a thin vibrating diaphragm element in the facepiece of this mask, somewhat better speech transmission was possible than in the service mask. Yet this mask had certain deficiencies. At a conference on 23 March 1943 the facts were brought out that the mask was unnecessarily burdensome, that it might make the wearer an easier object of sniper fire, that its voice transmission qualities were only slightly better than the standard service mask, and, above all, that it seemed impossible to turn out a diaphragm with an assurance that it would remain gas tight.[29] After a review of this mask by using arms and services in June 1943, when the critical components, complex manufacture, and slight acoustical properties of the mask were pointed out, the Signal Corps, Army Air Forces, Armored Force, Cavalry, and Infantry rejected it. The CWS stopped production and apportioned existing stocks among the Field Artillery, Coast Artillery, and Antiaircraft Artillery, who still wanted a diaphragm mask.[30] When in 1945 requests continued for a better speech mask, the CWS developed a new lightweight diaphragm gas mask, having improved acoustical properties. It was intended to replace earlier diaphragm masks carried by tank crews and by radio and telegraph operators. The war ended before it could be put into production.

Another special mask, first requested in 1940 and again by the Chief Surgeon, ETO, in 1944 was the headwound mask, for soldiers in field hospitals with head, face, jaw, or neck injuries.[31] It consisted of a vinylite hood

[27] 2d Ind by AGF on Ltr, Armored Board to CG Armored Center, Fort Knox, 23 Aug 45, cited in CWTC Item 1547, Revised Military Characteristics for Collective Protector for Tanks, 28 Mar 46, p. 3.

[28] CWTC Item 306, Standardization of Mask, Gas, Diaphragm, MIII-IXAI-IVA1, 21 Jan 41.

[29] Memo, OC CWS Conference, 23 Mar 43. AGO 337-1043.

[30] CWTC Item 731, Reclassification of Mask, Gas, Diaphragm, 11 Jun 43.

[31] (1) CWTC Item 286, Gas Masks for Head Wound Casualties, 19 Nov 40. (2) CWTC Item 955, Military Characteristics for Gas Mask for Head Wound Casualties, 17 Mar 44.

WALT DISNEY WITH STAFF MEMBERS OF CHEMICAL WARFARE SERVICE, *January 1942, meeting to discuss a Mickey Mouse gas mask for children. From left: Col. George J. B. Fisher, Col. Maurice E. Barker, Walt Disney, General Porter, and General English. Note picture of mask, left background.*

with a wide, transparent vinylite eyepiece, an M11 canister, and a vinylite carrier. Although the CWS did not solve completely the problem of obtaining a gas tight seal for patients with neck wounds, it nevertheless standardized the mask at the request of the SGO in August 1944 and supplied them to the theaters.[32] Continuing work resulted in a much better neck seal on this mask, but since the danger of gas warfare receded the improved model was destined only for limited procurement.[33]

The CWS first planned a civilian gas mask in 1937. By 1940 the service had decided that the design of the Zapon-type mask, as it was called, was not satisfactory, and had replaced it by another of rubberized fabric.[34] At the request of the Office of Civilian Defense, the service redesigned this gas mask with its snout-type canister in five sizes for civilian use and obtained permission to produce it with laminated and, later, sheet rubber

[32] (1) CWTC Item 1161, Standardization of Mask, Gas, Headwound, M7-11-9, 31 Aug 44. (2) Hemleben, CWS-MIT Development Laboratory, pp. 153-60.

[33] CWTC Item 1165, Classification of Mask, Gas, Headwound, E44-M11-E11, 31 Aug 44.

[34] (1) CWTC Item 11, Mask, Gas, Noncombatant (Zapon-type)—Classified as Standard, 11 Apr 39. (2) CWTC Item 151, Mask, Gas, Noncombatant, MI-I-I Standardization, 14 May 40.

facepieces, to eliminate the uncomfortable chin seam of the fabric model.[35] With the growing shortage of rubber, the CWS-MIT Laboratory worked out a process for manufacturing faceblanks from impregnated felt. The CWS produced large numbers of this type of civilian gas mask under experimental contract before closing the program. Other civilian masks included the Mickey Mouse mask for children, designed by Walt Disney, and the infant protector, a pliofilm respirator for children too young to be fitted with a mask.

On the basis of World War I experience, the CWS had devised gas masks for horses and mules, as well as leggings, capes, eyeshields (since the horse gas mask did not cover the eyes), and other protective equipment. The mask was in the process of standardization early in 1943 when the mechanization-minded AGF canceled all requirements for horse protective equipment. Late in 1944, as the 10th Mountain Division prepared to go overseas with its complement of horses and mules, AGF reversed the order.[36] Subsequently, the service standardized capes and eyeshields for the Mountain Division animal trains. It also designed masks for the dogs used on security patrols and for messenger work overseas, and a baglike mask to protect Signal Corps pigeons.[37]

Estimates of the relative value of American, Japanese, and German gas masks varied somewhat with the specimen and the examiner, but on the whole scientists felt that the U.S. masks, despite their weight, discomfort, poor vision, and other disadvantages, were "probably the best worn by any army." [38] The Japanese Army masks, though lighter, more compact, and well constructed, would not stand the wear and tear of American masks, and the canister gave somewhat less protection, particularly against hydrogen cyanide and cyanogen chloride.[39] One model of Japanese noncombatant mask was superior in material, workmanship, and protection to the American counterpart, but other models were inferior.[40] The Japanese had specialized masks, including a Navy diaphragm and a horse mask.

[35] CWTC Item 426, Rubber Face for Noncombatant Gas Mask, 16 Dec 41.

[36] (1) Canceled in view of policy established in Ltr, CG SOS to C CWS, 20 Oct 42, sub: Deletion of Mask, Gas, from T/BA 2 and T/A 6, cited in CWTC Item 698, Cancellation of Requirement for Horse Protective Equipment, 23 Apr 43. (2) CWTC Item 1297, Reclassification of Mask, Gas, Horse, M5, 22 Mar 45.

[37] (1) CWTC Item 1150, Standardization of Mask, Gas, Dog, M6-12-8, 31 Aug 44. (2) CWTC Item 359, Protective Pigeon Bag, M2, 22 Jul 41.

[38] W. C. Pierce, The Gas Mask, NDRC Misc Pub 626, 1 Aug 44, p. 19.

[39] (1) WD Intel Bull, Oct 42, pp. 47, 48. (2) CW Intel Bull no. 10, 1 Sep 44.

[40] (1) Hemleben, CWS-MIT Development Laboratory, p. 215. (2) Japanese Chemical Warfare.

In the opinion of Generalleutnant Herman Ochsner the American mask "was highly effective in protection against gas and in that respect would meet even the highest demands." [41] But it was too heavy for the German Army, which favored a compact model with a drumlike canister fastened directly to the mask. The early German canister gave lower protection than the American, although it was improved later in the war.[42] The Germans had gas masks for noncombatants, headwound casualties, horses, dogs, and pigeons.

Collective Protectors

The collective protector was a machine designed to draw contaminated air from outside a gasproofed shelter and purify it for circulation within. The collective protectors available at the start of the war were the M1A1, a 1,210-pound unit for use in large permanent installations such as seacoast forts, headquarters, and field hospitals, and the M2A1, a 615-pound unit, for temporary field tent installations.[43] In 1942 the CWS–MIT Development Laboratory provided the M3 field collective protector, a small 10-man unit for installation in Ordnance machine shop trucks, office trailers, mobile surgical units, and CWS mobile laboratories. The chief difficulty lay in obtaining an air-tight seal in these vehicles. The CWS Development Laboratory at last devised a special canister with an Electrolux dust-precipitator air blower which supplied purified air through corrugated rubber hoses to facepieces worn by the tank occupants.[44] The Armored Medical Research Laboratory approved the device after tests in 1944 at the Ordnance Desert Proving Ground, Calif., but then reversed its decision on the basis of later tests at Camp Polk, La., when it found no physiological or operational advantages, under high humid conditions, over the individual combat mask. Edgewood Arsenal produced more than 1,100 M1A1's and 2,500 M3's during the war.[45]

At the request of the Office of Civilian Defense late in 1941, the CWS–MIT Development Laboratory devised a collective protector for civilian air raid shelters. Under power operation it would protect adequately 40 to 50 persons; when hand-operated, 20 to 25 people. The service constructed a

[41] Generalleutnant Herman Ochsner, History of German Chemical Warfare in World War II, pt. 1, The Military Aspect, p. 33. Chemical Corps Historical Studies, No. 2.

[42] CW Intel Bull No. 46, pt. II, Recently Captured Material. 15 Dec 44.

[43] CWTC Item 132, Standardization of Large Field Collective Protector, 12 Mar 40.

[44] CWTC Item 1242, Military Requirement and Military Characteristics for a Collective Protector for Tanks, 11 Jan 45.

[45] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 25.

number of experimental models of the lightweight machine before the requirement was rescinded.[46]

The Germans developed a number of collective protectors for civilian gasproof shelters, armored vehicles, and small fortifications. The pumps used to draw outside air through the canister were generally centrifugal air blowers operated by electricity, with a crank for turning the fan by hand if the electricity failed. An unusual model had a double-action bellows with a long handle that could be pumped up and down to draw air through the protector.

Japanese collective protectors were similar to those used by European nations and the United States. An ingenious model capable of purifying air for forty persons derived the power for pumping the bellows from a geared bicycle mechanism.[47]

Eyeshields, Dust Respirators, and Individual Protective Covers

The British, naturally more apprehensive than the United States about gas warfare, supplied their troops from the beginning with such items as eyeshields, protective capes (covers, in American military terminology), helmet hoods, light oilskin jackets, overboots, oilskin trousers, oilskin valises for antigas equipment, gasproof sacks for vehicles, oilskin stretcher covers, and antigas-pathway paper rolls. Even though the CWS procured many of these items for the British on lend-lease, the CWS itself later adopted only the first two items.

When this list of British equipment was submitted to the U.S. arms and services in an effort to establish their requirements, representatives of the Navy, Armored Force, Quartermaster, Field Artillery, and Engineers expressed an interest in almost every item, the Infantry and Medical Corps indicated interest in several items only, and the Signal and Ordnance wanted almost none.[48]

Believing that the enemy would attack with low-flying aircraft spraying vesicant agents, the CWS urged adoption of the eyeshield, so that troops on the march and in the field would have special protection against this hazard. After rejection of this item in the summer of 1942 by the Desert Warfare Board, which felt that its dust goggles offered equal or superior protection, AGF repeatedly turned down the eyeshield. When the

[46] CWTC Item 794, Standardization of Protector, Collective, M4, 3 Sep 43.
[47] Japanese Chemical Warfare.
[48] CWTC Item 335, New Items of Individual Protective Equipment, 27 May 41.

CWS suggested that other arms would need it, the AGF insisted that either goggles, the protective cover, or the soldier's helmet brim offered adequate eye protection against spray attack.[49] Finally, after General Eisenhower asked for eyeshields for his North African theater forces, "regardless of any objection to them," the CWS procured and issued them.[50]

The first eyeshields that went overseas consisted of simple cellulose acetate eyepieces bent to fit tightly over the temples, rimmed with a felt strip, and held in place by an elastic head strap. Toward the end of the war the service designed an eyeshield which could be folded and carried in the pocket. This item was made in both clear and green-tinted acetate, the green for protection against snow glare and sunlight, and it could be worn over spectacles. Two small ventilation holes in the upper corners of the eyepiece reduced the fogging experienced with the first model.[51] Because of the cheapness and excellent design of the eyeshield, the AGF later recommended that it replace the expensive sunglasses and dust goggles being issued. It proved to be one of the most useful of troop items. Eyeshields were intended originally to ward off drops of liquid mustard or other vesicant agents, but they would have been of signal importance if the German Army had suddenly uncovered its nerve gases, one drop of which in the eye could be lethal.

German antigas eyeshields came in a pouch containing two colorless and two yellow-green eyeshields. In designing the shields the German Army kept in mind the fact that they could protect the soldier's eyes against intense sunshine and snow glare as well as against chemicals. The Germans manufactured only a limited quantity of eyeshields and, as far as known, never issued them.[52]

A nongas warfare item turned over to CWS for design and procurement was the M1 dust respirator, first requested in 1940 by the Armored Force, and soon after by the Infantry, for protecting troops against coarse, wind-driven particles. Initially, it consisted of a relatively large rubber faceblank with a felt filtering medium stitched to the blank. Later the service reduced the bulk and weight of this respirator by using lightweight felt on a wire and rubber frame, with rubber outlet valve and headband.[53]

[49] (1) CWTC Item 541, Unfavorable Consideration of Eyeshield, M1, 4 Aug 42. (2) CWTC Item 623, Eye Shields, 24 Nov 42.

[50] CWTC Item 693, Standardization of Eyeshields, M1, 23 Apr 43.

[51] CWTC Item 742, 11 Jun 43, and Item 1405, Standardization of Eyeshield, M2, 2 Aug 45.

[52] (1) German Chemical Warfare Materiel, p. III-F-22. (2) German Chemical Warfare, p. 165.

[53] (1) CWTC Item 329, Standardization of Respirator, Dust, M1, 1 Apr 41. (2) CWTC Item 612, Standardization of Respirator, Dust, M2, 24 Nov 42.

Near the end of the war, technicians designed a simple, expendable respirator that the Cavalry Board found to be more durable and more comfortable and to give greater protection than earlier models.[54]

The Army first issued individual protective covers to theater troops late in 1942. Developed at the request of the Air Forces for the protection of air base personnel against vesicant spray from aircraft, the cover became a Quartermaster item of general issue. It consisted of a specially treated, large, cellophane bag folded into a small 4 by 7½-inch packet. A tear-tape device enabled a soldier with rifle or carbine to open the cover and don it sack-fashion in ten to twelve seconds. This cover, though it protected the soldier, enveloped and virtually immobilized him; it was an emergency measure and no substitute for protective clothing.[55]

German troops had no protection similar to American and British covers and capes, but relied on a *gasplane* or antigas sheet made of treated crepe paper, parchment paper, wax paper, rubberized fabric or plastic coated fabric, about four feet by seven feet in size. Troops could have used these sheets to cover supplies or weapons, and could convert them into protective capes by cutting a hole in the center.[56]

The Japanese Army had protective capes and sheets. The cape, four and one half by eight feet in size, came with a triangular-shaped hood which the soldier could slip over his head, while the rest of the cape could be wrapped around his body. The cape was constructed from brown, lightweight paper, and, not sturdy enough to withstand decontamination, would have to be thrown away after use. The sheet, made of rubberized fabric eight feet square, was intended as a cover for the soldier or equipment during an attack.[57]

Protective Clothing and Impregnites

The two-layer cotton permeable suit of World War I, its outer layer impregnated with 45 percent rosin and 55 percent rosin oil, reportedly gave almost complete protection against mustard vapor for forty minutes.[58] The demonstrable superiority of the permeable protective suit of World War II, an impregnated herringbone-twill outfit offering effective protection

[54] CWTC Item 1360, Classification of Respirator, Dust, Lightweight, E23, 24 May 45.

[55] (1) CWTC Item 575, Protective Cape for Army Air Forces, 29 Sep 42. (2) TM 3-290, pp. 42-45.

[56] Military Intelligence Service, WD, Special Series, no. 16, Enemy Capabilities for Chemical Warfare, 15 Jul 45, p. 42.

[57] Japanese Chemical Warfare.

[58] *Medical Aspects of Gas Warfare*, pp. 762-64.

against both mustard vapor and fine mustard spray, derived in part from improvements in design. The CWS attacked basic design problems in cooperation with the NDRC, the Navy, and the Quartermaster Corps, which procured, stored, and issued the clothing. The high standards of design set by the service seemed all but unattainable. Even as the war ended, work was still in progress to eliminate the small degree of leakage past the closures and seals of the jacket and shorts. However slight, such leakage might produce serious blister injuries, since the areas of the body most vulnerable to the effects of mustard were the scrotal and neck regions.[59]

The superiority of World War II protective clothing over world War I type resulted mainly from an impregnite, a chloroamide designated CC-2. The search in World War I and after for a chemical that would react rapidly with mustard, and which was sufficiently stable on fabric to ensure reasonably good storage qualities, led to the discovery of CC-2 in 1924 and its intermittent manufacture on a pilot plant scale at Edgewood Arsenal.[60] In 1928 the CWS accepted CC-2 as a standard impregnite. The formula for CC-2 was one of the most closely guarded secrets of the Chemical Warfare Service. Under Navy and NDRC auspices, between 1940 and 1945, scores of new compounds were tested in search of possibly better impregnites, but none proved superior to CC-2.

In contrast to the Americans, the Germans did not issue impregnated clothing. They carried on experimental work, but a shortage of materials kept them from getting very far. The few articles that they impregnated experimentally were stiff, smelly, and caused dermatitis.[61]

Protective Ointments

World War I efforts to devise an ointment that would prevent mustard lesions were unsuccessful, and the attempts in the years between the wars were equally discouraging.[62] In the light of American knowledge in 1940, sag paste (*s*alve *a*nti*g*as), as the ointment of 1918 was called, was "even worse than useless," though its issue to troops may have been "useful

[59] For adverse comment on the design imposed by the CWS on all herringbone twill clothing, standard issue as well as protective clothing, see Erna Risch, *The Quartermaster Corps: Organization, Supply, and Services,* Volume I, UNITED STATES ARMY IN WORLD WAR II (Washington, 1953), p. 97, n. 47.

[60] Capt William M. Creasy and Souren Z. Avedikian, Impregnite I. EATR 272, 31 Jul 39.

[61] German Chemical Warfare, p. 164.

[62] E. B. Vedder, *The Medical Aspects of Chemical Warfare* (Baltimore: Williams & Wilkins, 1925), pp. 150-51.

psychologically."[63] In 1940 the CWS renewed the search first in its own and in Navy laboratories and then with the help of the Committee on the Treatment of Gas Casualties (CTGC), the Committee on Medical Research (CMR), and the National Defense Research Committee (NDRC). The aim was to find something that would penetrate the skin as fast or faster than mustard and neutralize the mustard and its decomposition products before destruction of the cells and tissues. This objective was based on the World War I theory that mustard penetrated the cells and released hydrochloric acid which then killed the cells and caused blisters.

Despite World War II efforts scientists still were unable to determine the precise mechanism of mustard action, although they suggested a promising theory that the primary action might be on essential cellular enzymes rather than on the cell as a whole.[64] What seemed necessary to combat the action, therefore, was still believed to be a quick-penetrating neutralizer. Scientists speculated that this substance had to be a chlorine compound since chlorine alone seemed to destroy mustard effectively with the least injury to the skin.

In 1940 researchers began a series of tests with two promising ointments, azochloramid with triacetin as its vehicle, and dichloroamine-T, also in triacetin. The latter, produced by the Monsanto Chemical Co., appeared to be the less irritating of the two and to possess some effectiveness, but it was never entirely satisfactory owing to difficulties in obtaining quantities of the basic ingredient in a sufficiently pure form. The service issued large quantities of protective ointments containing variants of the dichloramine-T formula and successively designated M1, M2, M3, and M4.[65] These ointments were the best available at the time and under temperate climatic conditions were satisfactory decontaminants. Later tests revealed that under hot weather conditions they might be excessively irritating to the skin.[66]

In the summer of 1941, meanwhile, Navy chemists in the laboratories at Edgewood and in their own research laboratories at Bethesda, Md.,

[63] CWTC Item 166, Subcommittee Report on Standardization of Protective Ointment, 16 Jul 40.

[64] *Advances in Military Medicine,* II, 549–51.

[65] The confusing story of M1 protective ointment is told in CWTC Item 166; CWTC Item 280, Request for Standardization of Ointment, Protective, 19 Nov 40; CWTC Item 330, Request for Standardization of Ointment, Protective, M2, 1 Apr 41; CWTC Item 506, Redesignation of Ointment M1 to M4, 2 Jun 42.

[66] (1) Misc Rpt, Col Cornelius P. Rhoads, MC, Report of Medical and Toxicological Factors Pertinent to CW in the SWPA (12 May 44), p. 12. MDR 109.1 Tech Lib A CmlC, Md. (2) Interv, Hist Off with C.W. MacFarlan, 26 Feb 57.

devised a series of chlorine compounds, one of which, S-330, was highly effective against mustard and could be better tolerated on the skin.[67] The Army adopted an ointment, M5, containing S-330 as its base in December 1943. The following year the service issued the M5 protective ointment kit, containing four ¾-ounce tubes of M5 ointment and one 3-gram tube of BAL eye ointment, to troops in the field.[68]

Good as it was, M5 ointment acted primarily to destroy vesicant liquid on the skin; it could not to any significant degree neutralize mustard that had penetrated the skin. The soldier had to apply it within two to five minutes. After that the blister agent penetrated the skin and its action was irreversible. Nevertheless, it was a highly serviceable ointment.[69]

The Japanese Army issued individual decontamination kits to its troops for destroying vesicant agents on the skin. The kit contained powder that formed a paste with water, and absorbent cotton for swabbing the paste on the mustard area. The paste could not be applied as quickly as ointment, since the soldier had to mix the ingredients before use, and this was a vital factor in the tropics where mustard had to be destroyed within a minute or two if burns were to be prevented. Furthermore, a paste had little prophylactic value in contrast to an ointment.[70]

The German Army issued two decontaminating agents to its troops. The first was stabilized calcium hypochlorite, in tablet form, referred to as Losantin. These tablets had to be made into a paste with water, applied to the skin for a few minutes, and then washed off. The second decontaminant was a thickened ointment of chloroamine-T, which was swabbed on, allowed to stand, and finally washed off. Neither the Japanese nor the German personal decontaminants approached the American M5 ointment in efficiency and all-around usefulness.[71]

Medical Kits and Supplies

Prior to 1942 the only first-aid kit for gas casualties was one prepared in 1933 by the CWS's Medical Division for use in chemical plants at Edge-

[67] (1) The Navy standardized it in August 1942; see Noyes, *Chemistry*, p. 210. (2) Comparative studies of the Army and Navy ointments appear in Marion B. Sulzberger, "Protection and Treatment of the Skin Exposed to Blister Gases," *Advances in Military Medicine*, II, pp. 591-96.

[68] (1) CWTC Item 854, Standardization of Ointment, Protective, M5, 3 Dec 43. (2) CWTC Item 1018, Standardization of Kit, Ointment, Protective, M5, 5 May 44.

[69] (1) *Advances in Military Medicine*, II, pp. 595-96. (2) Noyes, *Chemistry*, pp. 181-212. (3) Lt. Col. D. J. C. Wiseman, compiler, "The Second World War: 1939-1945, Army, Special Weapons and Types of Warfare," vol. I, *Gas Warfare* (London: British War Office, 1951), p. 205. Hereafter cited as Wiseman, *Gas Warfare*.

[70] Enemy Capabilities for Chemical Warfare, pp. 142-44.

[71] German Chemical Warfare, pp. 165-66.

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wood Arsenal. Although the service revised and tested the kit in 1938 as a possible military item, there appeared to be no military requirement for it and the work was stopped.[72] Thus as war approached the CWS did not have a chemical warfare medical kit, nor did the Medical Department supply catalog of 1939 contain more than one or two of the drugs and preparations that had been reported by the Edgewood laboratories up to that time as effective remedies for gas casualties.

The service drew up a list of equipment and materials that should be included in regimental medical-detachment supply. The list was approved by The Surgeon General and the Medical Department Board, whose responsibility it was to standardize such equipment. They recommended that the drugs and impervious gloves and aprons in the list be packed in a Medical Department chest for issue to each regimental medical section, while the more bulky equipment such as the permeable protective clothing for medical personnel handling gas casualties, the headwound masks, and the field collective protector be held in rear area depots until required.[73] In March 1942 the service standardized the first gas casualty chest, containing drugs, gloves, and aprons. The chest was modified in December 1943 as the M2 gas casualty set, and in May 1944 it was completely revised when its unwieldy trunk-type construction, weighing almost 300 pounds, was scaled down to a 45-pound Alpine pack-type set. This final gas casualty set consisted of 2 canvas pack inserts containing 6 impermeable aprons, 6 pairs of impermeable gloves, and the gas casualty treatment kit.[74]

The CWS procured more than 10,000 gas casualty treatment kits. The contents of the 1945 kit, representing the best efforts of wartime medical research in the treatment of chemical agent injuries, and containing in lesser or greater quantities the material also found in the first-aid kit and veterinary set, included BAL ointment (for removal of arsenicals from the skin), petrolatum and amyl salicylate (for removal of mustard from the skin), sodium sulamyd (to prevent blister gas eye infection), copper sulfate solution (to remove WP particles from the skin), copper sulfate powder (to replenish solution), sulfadiazine tablets or penicillin (to prevent secondary infection), a floating white soap (for decontamination), BAL eye ointment (for any liquid blister gas contamination of eyes), eye and

[72] Charles A. Rouiller, First Aid Kit for Chemical Warfare Service Plants. EATR 291, 7 Dec 38.

[73] Rpt, Medical Department Board, Medical Field Service School, Carlisle, Pa., 10 Jan 41, sub: Chemical Protection, Medical, Project No. 171.

[74] MRL (EA) 14, Louis Venet and M. J. Oehlberg, Gas Casualty Set for Medical Units, 18 Feb 44.

nose drops (to relieve pain of blister gases), chloroform (to relieve irritant smoke distress), amyl nitrite ampules (for hydrocyanic acid poisoning), ophthalmic discs, fluorescein, and atropine sulfate (for treatment of eye injury), calamine concentrate (for relief of mustard burn itching), forceps (to remove WP particles from the skin), a 4-ounce plastic bottle (for preparing calamine solution), and a screening water testing kit (to detect agents in water supplies).[75]

Shortly after the appearance of the gas casualty chest in 1942, a small gas casualty first-aid kit, evolved from the earlier plant kit, was standardized and issued on the basis of one to each twenty-five individuals and as an accessory of vehicular equipment. Its contents, based on developments reported in TM 8–285, were dichloramine-T in triacetin, hydrogen peroxide solution, copper sulfate solution, M1 eye solution, amyl nitrite, pontacaine ointment, and M4 protective ointment.[76] Three years later, in 1945, this same first-aid kit contained BAL ointment, chloroform, amyl nitrite, copper sulfate, eye and nose drops, calamine lotion, and the M5 protective ointment kit, the latter consisting of four tubes of M5 protective ointment and one tube of BAL eye ointment.[77] Over 250,000 of these kits were procured for shipment overseas.

In developing special kits and chests, the CWS's Medical Division obtained standard medical items from the Army Medical Purchasing Office in New York, but in designing the sets, in packaging, and in stocking special items, it had to have direct contact with industrial firms. It called upon Bauer and Black, the Davis Emergency Equipment Co., Du Pont, Lambert Pharmacal, Dow Chemical, Rohm and Haas, the New England Collapsible Tube Co., Merck, Squibb, Lederle, and others. In the final procurement of the gas casualty chests, kits, and other items of issue developed at Edgewood, the Army's medical department did the contracting. The responsibility of the CWS's Medical Division was limited to ascertaining the military requirement and developing and standardizing special equipment and supplies.

In contrast to the American Army's medical kits and sets, the German Army depended on individual issue of emergency items. The German soldier, for example, was told to wash the skin with soap and water immediately after contamination. A special soap, known as Mersol, was issued

[75] The contents of the first-aid and treatment kits are listed in the various editions of TM 8–285. For further details of these supplies, see Cochrane, Medical Research in Chemical Warfare, pp. 137–52.

[76] FM 21–11, First Aid for Soldiers, 8 Apr 43, pp. 100–103.

[77] TM 8–285, Apr 1945, p. 102.

for use at decontamination centers. Ten Losantin tablets for making a decontamination paste were issued to German troops, as well as an ointment of chloroamine-T in water, for the same purpose. Small, cloth covered ampules containing ammonia, chloroform, alcohol, and ether were issued to counteract the effects of the sneezing gas DM, and a suspension of chalk in copper sulfate solution was issued for WP burns.[78]

Protection of Food and Water Supplies Against Toxics

In 1938 the CWS began work on purification of water and continued it until early in 1945.[79] Scientists devised an emergency method for purifying water for small units, employing carbon and special filter cartridges in a Lyster bag, and then chlorinating the water thus treated. However, no better method could be devised for removing agents from large bodies of water, such as found at a water supply point, than the standard procedure used by municipal water control stations (activated carbon and alum), and this was a Corps of Engineers responsibility.[80]

The service's efforts to detect the presence of toxics in water were more successful. In February 1942, with assistance of an NDRC group under A. M. Buswell of the University of Illinois, the CWS began work which led to the development of a kit with which a soldier could detect contaminants. Chemists at Illinois devised specific tests for detecting the presence of sulphur and nitrogen mustards, arsenicals, selenium, and other heavy metals in water, while J. H. Yoe at the University of Virginia found a test for fluorine compounds in water.[81] On the basis of this work, the Army adopted a treatment-control water-testing kit in March 1944. This kit made possible the quantitative analyses necessary to determine treatment dosages for contaminated water and to establish the effectiveness of such treatment.[82] A year later the service produced a food testing kit to detect the presence of sulphur and nitrogen mustards, as well as other toxic agents, on foods and food containers.

[78] German Chemical Warfare, pp. 165–66.

[79] Ltr, C MRD to TSG, 9 Oct 39, sub: Purification of Water Contaminated with Chemical Warfare Agents. Cited in Cochrane, Medical Research, p. 478.

[80] A survey of the research on this problem appears in Joseph M. Sanchis, "Chemical Warfare and Water Supplies," *Journal of American Water Works Association,* 38 (1946), 1179–96.

[81] Noyes, *Chemistry,* pp. 223–26.

[82] "The Medical Department in World War II," *Environmental Hygiene,* vol. II, *Preventive Medicine in World War II* (Washington, 1955), pp. 103–05.

Treatment of Gas Casualties

In 1939 the CWS was confronted with the same problems in treating gas casualties that it had faced back in 1918. Researchers discovered no treatment for pulmonary edema caused by phosgene poisoning, for bronchopneumonia that set in following the inhalation of mustard vapors, or for lesions or ulcers of the eyes and skin caused by liquid or gaseous vesicant agents. The CWS began to attack each of these problems, later receiving assistance from the NDRC and the Committee on the Treatment of Gas Casualties.

By the close of World War II the medical research teams which engaged in basic studies on the therapy of phosgene and other chemical irritants at Northwestern, at Yale, at Chicago, and at the University of Pennsylvania had learned many things about the physiology of phosgene poisoning—principally that the mode of action was the vigorous and usually fatal injury of the lung tissue, resulting in waterlogging of the lungs. They learned little or nothing about treating it, other than that among animals surviving the flooding of the lungs, the anoxia or oxygen starvation of the tissues that resulted would respond to pure oxygen inhalation.[83] The Boothby-Lovelace oxygen therapy apparatus, developed at the Mayo Clinic and the Aero Medical Research Laboratory at Wright Field, Ohio, and standardized as Medical Department equipment, was a partial answer to the problem. A subsequent development, to provide more efficient consumption of oxygen in the field, was an oxygen therapy apparatus with distributing hose, to permit simultaneous administration of oxygen to twenty patients.[84] Oxygen was the one effective therapy for phosgene poisoning. Codeine might relieve the cough, morphine could be administered to quiet the patient, and when the edema subsided, antibacterial therapy (penicillin or sulfadiazine) could be administered in order to prevent pulmonary infection. Beyond this there was little that could be done.

Useful in the plants where phosgene was manufactured was the discovery that hexamethylenetetramine (HMT) was an effective prophylactic against phosgene poisoning. The compound rapidly combined with phos-

[83] For detailed studies of phosgene therapy, see chapter by Ralph W. Gerard, "Recent Research on Respiratory Irritants," *Advances in Military Medicine*, II, pp. 565–87.

[84] (1) W. M. Boothby, E. W. Mayo, and W. R. Lovelace, "One Hundred Per Cent Oxygen," *Journal of the American Medical Association*, 113 (1939), pp. 477–81. (2) MRL (EA) 6, M. Galdston, Distributing Hose for Field Oxygen Therapy, 6 Nov 43.

gene as it entered the lungs and blocked its action on the tissue. While such a preventive had certain values in the factory and laboratory, it was of little use to the soldier who could not be continually inoculated against first one agent and then another in this manner.[85]

Mustard, the most important of the blister gases, is a disabling rather than a killing agent, its action painless and undetected since it is rapidly absorbed by the skin. The liquid, spray, and vapor produce severe eye injury, blisters on the body, and injury to the lining of the respiratory tract exposing it to infection. In World War I the bronchopneumonia that followed inhalation of mustard gas was responsible for most deaths from this agent.

Perhaps more work was done on the blister gases between 1940 and 1945 than in all the previous years put together. The CWS and its cooperative agencies studied the therapy necessary to prevent secondary infection, and methods of decontaminating liquid mustard absorbed through the skin.[86] Before the discovery of the sulpha drugs only supportive treatment, that is, careful nursing, cleanliness, and warmth, was possible for the secondary infection, usually bronchopneumonia, following inhalation of mustard gas. Of the new drugs, sulfathiazole seemed to have the greatest protective value against the secondary infection. As the supply of penicillin increased, pneumonia cases which showed resistance to the sulpha compound could also be treated successfully. With these drugs available the secondary infection was no longer to be greatly feared.

The antimustard preparation, M5 protective ointment, while not the final answer to mustard decontamination and prevention of mustard effects on the skin, was the most satisfactory preparation devised during the war for this purpose. Researchers found no clear-cut superiority for any therapeutic agent in the treatment of mustard burns of the skin, but they concluded that the use on third degree burns of sulfadiazine ointment and petrolatum containing silver nitrate was the best treatment for the burn-like injury.[87] As for contamination of the eyes by liquid mustard gas, nothing proved much more effective in preventing the rapid and destruc-

[85] MD (EA) MR 81, Therapeutic and Prophylactic Value of HMT in Phosgene Poisoning, 19 Mar 43.

[86] For the useful but essentially negative results obtained in studies of systemic mustard poisoning, see chapter by A. Gilman and M. Cattell, "Systemic Agents: Action and Treatment," *Advances in Military Medicine,* II, pp. 546–51.

[87] MRL (EA) 36, J. Wexler and L. H. Rasmusen, Evaluation of Local Treatment of Mustard Burns, 1 Sep 44. (2) See Sulzberger, "Protection and Treatment of the Skin Exposed to Blister Gases," *Advances in Military Medicine,* II, pp. 588–602.

tive penetration of mustard into the cornea than immediate irrigation of the eyes with water.

Lewisite, discovered too late for use in World War I, received its share of attention from researchers. In the winter of 1940–41, a group working under R. A. Peters at Oxford University experimented with a compound called DTH (dithioglycerol) or BAL (British antilewisite) which was quite effective in preventing arsenical poisoning by lewisite.[88] Under the direction of the Committee on the Treatment of Gas Casualties, extensive studies of the new substance were undertaken in CMR and NDRC contract agencies, as well as at the Edgewood laboratories.

One of the first American results of the BAL investigation was the development by the Du Pont laboratories under CWS contract of M1 eye solution, a 5 percent solution of 2,3-dimercaptopropanol in ethylene glycol.[89] Shortly after this a series of experiments indicated that a 5 percent BAL ointment was much less difficult to apply to the eyes and that, despite the pain of lewisite eye contamination, untrained personnel could probably apply effective quantities of the ointment to themselves. The service standardized BAL eye ointment in July 1943.

Hydrogen cyanide, another of the Army's toxic agents, became the subject of a long series of toxicological and medical investigations. Hydrogen cyanide was the fastest acting nonpersistent agent known, because after a breath or two respiration could no longer be suppressed and before the man could mask he might be unconscious.

The recommended treatment for acute cyanide poisoning was the insertion of crushed ampules of amyl nitrite under the gas mask. The protective or therapeutic effect of amyl nitrite seemed to lie in its ability to form methemoglobin in the blood, converting the cyanide into relatively harmless cyanmethemoglobin. It was known that a compound called p-aminopropiophenone was highly active in forming methemoglobin, and experiments at Edgewood determined that a man could tolerate sufficiently large injections of this substance, named PAPP by the Medical Research Laboratory, to provide complete protection against the effects of the cyanides. Even more important, PAPP was almost equally effective when taken by mouth.[90] This, however, was prevention and not therapy for cyanide

[88] (1) Gilman and Cattell, "Systemic Agents," *Advances in Military Medicine*, II, pp. 555–61. (2) W. R. Kirner, in Noyes, *Chemistry*, pp. 181–84.

[89] MD (EA) MR 85, Comparative Therapeutic Values of Various BAL Products and Certain Derivatives . . ., 7 Apr 43.

[90] (1) MRL (EA) Informal Monthly Progress Reports, 15 May 44, 15 Sep 44, and 15 Apr 45. (2) *Advances in Military Medicine*, II, pp. 554–55.

poisoning, just as HMT was an effective prophylactic against phosgene, and therefore suitable for protection in the laboratory but impractical in the field.

While it is true that positive and immediate militarily useful results from chemical warfare medical research were relatively meager in view of the great effort made, under the threat of gas warfare the CWS had no choice but to explore every toxic agent suspected of being of interest to the enemy and every known or conjectured aspect of gas casualty aid and treatment. To this end the full resources of medical science in this nation and in the British Commonwealth were made freely available, enabling the Chemical Warfare Service to command a degree of assistance never achieved before. The common effort was rewarded on two levels: first, there was an enormous accumulation of original scientific data, new instrumentation, and more precise methodology, the benefits of which may be estimated only in the event of gas warfare in the future; and, secondly, substantial contributions were made both to fundamental and clinical progress in medicine.[91]

[91] (1) See Oscar Bodansky, "Contributions of Medical Research in Chemical Warfare to Medicine," *Science* (23 November 1945), 102. (2) *Advances in Military Medicine*, II, pp. 517–21, 543–44, 551–55, 559–60, 563–64, 587, 596, 602.

CHAPTER V

Biological Warfare Research [1]

In the years just before America's entry into World War II, both Germany and Japan were reported to be preparing for biological warfare and, it was believed, had devised agents capable of assailing the best defenses that medical science had evolved. In the United States there were skeptics who doubted the effectiveness of biological warfare against a modern army.[2] They reasoned that with the development of modern sanitary precautions, water purification, and insect and rodent control, the normal incidence of bacterial activity could largely be thwarted. Combat troops took the field supported by the best medical protection available and were armed with antitoxins, vaccines, and sera as a safeguard against diseases caused by some of the most harmful common bacteria. Furthermore, these skeptics felt, the problem of disseminating great quantities of bacteria in order to overwhelm any possible defense would present immense technical difficulties. But in their opinion the chief deterrent to initiating biological warfare was the danger to the side which unleashed it. Only an isolated enemy could be safely attacked, and there was no longer any such thing as an isolated enemy. On the other hand, American intelligence agencies reported that neither the Japanese, Germans, nor the embattled British shared this skepticism.[3] Nor did the Chemical Warfare Service, which had for years been interested in the potential problems of the bacterial weapon.

[1] The principal source in writing this chapter has been the monograph by Rexmond C. Cochrane, Biological Warfare Research in the United States, History of the Chemical Warfare Service in World War II (1 July 1940–15 August 1945), November 1947. (Hereafter cited as BW Research in the U.S.) In several cases it seemed advisable to cite the documents used in preparing the monograph.

[2] Maj. Leon A. Fox, MC, "Bacterial Warfare: The Use of Biologic Agents in Warfare," *Military Surgeon,* 72 (March 1933), 189–207, reprinted in 90 (May 1942), 563–79.

[3] BW Research in the U.S., pp. 12–13.

CWS Interest in Biological Warfare

Ever since the League of Nations Conference of 1924 and the Geneva Gas Protocol of 1925 linked chemical, biological, and incendiary warfare as related problems, the Chemical Warfare Service had regarded biological warfare as within its sphere of responsibility, and from time to time members of the service had prepared appraisals of its war potential.[4] In simplest terms, biological warfare may be defined as the intentional cultivation or production of pathogenic bacteria, fungi, viruses, rickettsia, and their toxic products, as well as certain chemical compounds, for the purpose of producing disease or death in men, animals, or crops. The definition also includes the development of defenses against these organisms and toxic substances. Potential agents might include the organisms producing the intestinal diseases of typhoid, cholera, and dysentery, through pollution of water supplies; the respiratory diseases of smallpox, diphtheria, epidemic meningitis, scarlet fever, and influenza, which are ordinarily dependent upon ideal epidemic conditions; the insect transmitted diseases of malaria, yellow fever, dengue, typhus, and plague; infections such as tetanus, anthrax, gangrene, and the pyrogenic diseases; agricultural diseases in the form of the boll weevil, corn borer, and Mediterranean fruit fly, as well as fungus diseases of crops and plants; and glanders, foot and mouth disease, Newcastle disease, fowl plague, and other diseases to which domestic animals and fowl are subject.[5]

In August 1941 the growing concern of the CWS led to the activation by oral order of the chief of the service of a unit designated the Medical Research Division, in the Technical Service at Edgewood Arsenal, to plan preliminary technical studies and to accumulate data "in connection with the medical aspects of chemical warfare, including bacteriology and immunization."[6] The division, consisting of five members,[7] examined potential sites, facilities, and personnel for an expanded biological program,

[4] (1) EA Mech Div Progress Rpt 442, Bacteriological Warfare, 24 Sep 24. (2) Rpt of CWS, 1926, pp. 8–9. (3) Fox, *op. cit.* (4) OC CWS Technical Study No. 10, Maj M. E. Barker, CWS, Bacteriological Warfare Possibilities, 28 Aug 39. In Technical Library A CmlC, Md.

[5] An unofficial account of BW potentialities, first prepared in 1942 and published after the war, is that by Theodor Rosebury, *et al.*, "Bacterial Warfare: A Critical Analysis of the Available Agents, Their Possible Military Applications, and the Means for Protection Against Them," *Journal of Immunology,* 56 (May 1947), 7–96.

[6] BW Research in the U.S., p. 13.

[7] Lt Col James H. Defandorf, Sanitary Corps (pharmacologist); Maj E. A. Richmond (entomologist); Maj A. T. Thompson, VC; Capt Frank M. Shertz (plant pathologist); and 1st Lt Luman F. Ney (physiological chemist).

prepared a bibliography of published literature on BW,[8] and drew up tentative programs for research. It also established contact with the British scientists working on BW at Porton, in Wiltshire, England, and with Canadian BW experts.[9]

The WBC Committee and War Research Service

Government agencies other than the Chemical Warfare Service also showed concern over the threat. These included the Institute of Health of the U.S. Public Health Service, the Council of National Defense, officers of the staffs of the Surgeons General of the Army and Navy, and G-2 of the Army.

In July 1941, Harvey H. Bundy, Special Assistant to the Secretary of War, called a meeting of representatives of the Office of Scientific Research and Development (OSRD), The Surgeon General, the CWS, and Army G-2, to discuss means for co-ordinating work in BW. As a result of this meeting the OSRD recommended to the Secretary of War that the National Academy of Sciences investigate the possibilities of BW.[10]

Two months before Pearl Harbor, the president of the National Academy and the chairman of the National Research Council asked Edwin B. Fred to help form and act as chairman of a committee to study and assess current potentialities of BW. A group of twelve scientists met on 18 November 1941, designated the WBC Committee (War Bureau of Consultants). Liaison members of the committe included Lt. Col. Maurice E. Barker, Lt. Col. James H. Defandorf, and 1st Lt. Luman F. Ney of the Chemical Warfare Service, as well as representatives of Ordnance, the Navy Bureau of Medicine and Surgery, The Surgeon General's Office, the Department of Agriculture, and the U.S. Public Health Service. The committee report to the Secretary of War in February 1942 declared the BW was distinctly feasible, that it was a potential threat to national security, and that steps should be taken at once to formulate defensive and offensive measures.

[8] OC CWS Technical Study 58, Biological Warfare: An Annotated Bibliography, 19 Jan 42. In Technical Library, A CmlC, Md.

[9] (1) OC CWS Orgn Chart, 1 Oct 41, approved 20 Aug 41, p. 23. (2) Memo for file, 30 Jun 42, sub: Proposed Orgn and Functional Chart, Bacteriological Warfare Service, CWS. (3) Memo, Col J. H. Defandorf, for file, 2 Nov 42, sub: Role of the CWS in the Development of Defenses against BW. Cited in BW Research in the U.S., pp. 23, 33. (4) Rpt, Col Defandorf, 20 Sep 45, sub: Research and Development in the Special Projects Division. CWS 314.7 BW File.

[10] Rpt, Henry I. Stubblefield, A Resume of the Biological Warfare Effort, 21 Mar 58. CMLHO C-511.111.

Through liaison established with the British BW group at the Porton Experiment Station, reports of the work there were made available to the CWS and the WBC Committee beginning in May 1942. By that time British research in BW had progressed from the theoretical stage and experimental study to actual small-scale production. Its director, Dr. Paul Fildes, urged that the United States undertake the large-scale studies that his group was not equipped to do, and in November he came to Washington to discuss the organization and operations of his group.[11]

Informed of the WBC Committee's findings, the War Department General Staff recommended, principally as a security measure and to avoid alarming the public, that the task of formulating defensive measures and procedures for retaliation be undertaken by a civilian agency.[12] The President therefore on 15 May 1942 authorized the Secretary of War to establish such an organization in the Federal Security Agency, a special nonresearch agency under the President. It was administered by Paul V. McNutt, and had been set up "to promote social and economic security, advance educational opportunities and promote public health." Thus obscured, the branch of FSA later known as War Research Service (WRS) came into being and was formally organized four months later with George W. Merck as director.

War Research Service was primarily an advisory body of eight members including Mr. Fred of the disbanded WBC Committee. It was charged with making a continuous survey of the BW situation and reporting its recommendations to appropriate government agencies, in particular the CWS, the Medical Department, the Bureau of Medicine and Surgery of the Navy, and the U.S. Public Health Service. Other agencies that came within the orbit of WRS included the Provost Marshal General's Office, the Assistant Chief of Staff G-2, Office of Naval Intelligence (ONI). Office of Strategic Services (OSS), Federal Bureau of Investigation (FBI), and the Department of Agriculture. The WRS was further charged with initiating research projects in universities and in private research foundations, with the proviso that these civilian agencies were to be "strictly limited to carrying out such projects as were assigned to the Chemical Warfare Service by WRS."[13] In other words, the Chemical Warfare Serv-

[11] Capt Frank M. Schertz, Biological Warfare, Jan 43, pp. 118–23, 128, 130, 144–46, 227–28. MS in Hist Off.

[12] Memo, C Spec Asgmts Br CWS to Spec Asst SW, 24 Aug 42, sub: Resume of CWS Activities in BW, 1 Oct 41 to Date. Cited in BW Research in the U.S., p. 22.

[13] Ltr, CG ASF to CofS, 8 Jan 44, sub: Bacteriological Warfare. Cited in BW Research in the U.S., p. 20.

ice actually issued the orders and directives necessary to implement WRS recommendations. The assigned research projects were to determine areas of investigation and special procedures necessary to maintain security, and to provide means of retaliation should the enemy resort to BW.

To act as technical adviser to WRS, on 16 October 1942 a new group, known as the ABC Committee, an arbitrary alphabetical designation, was formed with the help of the National Academy of Sciences and the National Research Council. Its chairman was W. Mansfield Clark of Johns Hopkins University and among its members were Roger Adams and Dr. Milton C. Winternitz, who were then also directing chemical and medical research work through OSRD agencies for the Chemical Warfare Service. Liaison members included Ira L. Baldwin, of the University of Wisconsin, and Comdr. Leroy D. Fothergill, MC, USNR (later the successive directors of the Special Projects Division, CWS); Colonel Defandorf, of the CWS Medical Research Division; Dr. Rolla E. Dyer, of the U.S. Public Health Service; and Mr. Merck, director of WRS.

On the assumption that BW was a real and immediate threat to this nation, War Research Service as its first action initiated through the Office of The Surgeon General antibiological warfare programs in the Hawaiian Department, the Caribbean Defense Command (including the Panama Canal Zone and Puerto Rico), the military districts of the United States, and in overseas theaters of operations. The programs instructed medical and security officers in detection and defense measures against biological attack and requested status reports of their plans and preparations.[14] Next, the WRS established approximately twenty-five contracts with universities and foundations for basic BW research. Most of these contracts were later transferred to the CWS. The War Reserach Service also established a special BW intelligence service, appointing the well-known novelist, John P. Marquand, as director of intelligence and information.

Taking the view that U.S. preparations for BW depended on enemy plans and capabilities, WRS officials at once directed Mr. Marquand to make arrangements to obtain all available information on enemy BW activity in possession of the Assistant Chief of Staff, G-2, ONI, Medical Intelligence Division, OSS, and the FBI. The meager material in their files suggested to Mr. Marquand that these agencies might not be properly alerted to manifestations of BW activity, and G-2 sent instructions for

[14] (1) WD Radio 4622 (CM-OUT-7818), 30 Jun 42. (2) The ABW Section set up in the Hawaiian Dept, composed of Sanitary and Medical Corps personnel, submitted its first periodic status report in July 1942.

collecting such intelligence to all military attachés and to theater and area commanders in the British Isles, North Africa, Middle East, China-Burma-India Theater, and the Pacific. When this alert also proved unproductive, Mr. Marquand himself went overseas, early in 1943, to consult with intelligence authorities and with theater surgeons. One of the results of his visit was that WRS, with the approval of the Office of the Surgeon General, recommended to the Secretary of War that blood samples be taken from prisoners of war to determine whether these individuals had been immunized against biological agents which the enemy might possibly employ.[15] By means of these samples WRS hoped to learn, for example, whether Japanese troops were being inoculated against yellow fever, a disease not present in the Far East, and whether Japanese or German troops were being protected against typhus, anthrax, dysentery, or botulism. It was also considered possible that improved methods of immunization developed by enemy scientists might thus be discovered. However, the Army finally decided that this kind of examination would not yield useful information.

CWS and the U.S. Biological Warfare Committee

Even before civilian research had begun under WRS, the Chemical Warfare Service had felt that civilian agencies could not achieve the degree of BW readiness for which ultimately the military had to assume responsibility. From long experience in preparing and maintaining a state of readiness for chemical warfare the service was certain that operational research and development in offensive aspects of BW, which required extensive laboratory and field trials, could not be delegated. Nevertheless until November 1942 the War Department continued to be reluctant to permit any military agency to particpate directly in the biological research being conducted in the universities. By then the inability of WRS agencies to carry out research beyond the laboratory stage, and the necessity of establishing military requirements, had become apparent. "In order . . . to obtain a clearer understanding of the dangers that confronted the nation" the WRS issued a succession of directives making the Chemical Warfare Service directly responsible for the military phases of the program.[16] To carry them out, the CWS began construction of Camp Detrick, the CWS

[15] BW Research in the U.S., pp. 129–30.

[16] Initiated with Memo, Dir WRS for C CWS, 10 Dec 42, sub: Request for Supplemental Research and Development. Cited in BW Research in U.S., p. 24.

biological warfare center, at Detrick Field, a National Guard airport near Frederick, Md., in April 1943, and by November it was in operation. The mounting threat of the German rocket program during 1943 gave added impetus to the urgency of American preparations for BW, for defense officials thought these rockets might readily be converted into efficient vehicles for BW agents. Current reports of the OSS and the BW Sub-Committee of the Joint Chiefs of Staff on the BW potential of the enemy also served to increase apprehensions. In January 1944 the Secretary of War directed the Chief of Staff to transfer the entire BW program from War Research Service to the Chemical Warfare Service. The Army authorized the CWS to begin preparations for possible retaliation in BW and, in cooperation with The Surgeon General, to provide means and methods for protection against attack.[17]

With the transfer of the program to the CWS, the Army dissolved the War Research Service, and assigned the responsibility for civilian research and development to the OSRD.[18] Mr. Merck was appointed special consultant on BW to the Secretary of War, with Mr. Fred and Mr. Marquand as scientific adviser and intelligence aide, respectively, to Mr. Merck. The ABC Committee was succeeded by the DEF Committee which was headed by Dr. O. H. Perry Pepper of the University of Pennsylvania, and which guided the technical program of the Special Projects Division, OC CWS, soon to be formed.

The U.S. Biological Warfare Committee, with Mr. Merck as chairman, came into being in October 1944, as a supervisory body to make recommendations to the Secretary of War and Chief of Staff on policy and to establish liaison with its British counterpart, the London Inter-Service Sub-Committee on Biological Warfare (ISSCBW). Members of the new committee included the Chief, Chemical Warfare Service; the director of the New Developments Division, WDSS; the director of the Office of Strategic Services; the chief of the Navy Bureau of Ordnance; the Surgeon Generals of the Army and Navy; the chief of the Military Intelligence Service; the Chief of Staff, ASF; the chief of the Requirements Section, AGF; the assistant chief of Air Staff Plans; the British Army Staff representatives; the director of Canada's Department of Chemical Warfare and Smoke; and the CWS representative on the ISSCBW. Research and de-

[17] 1st Ind, CofS to CG ASF, 14 Jan 44, and 2d Ind, CG ASF to C CWS, 15 Jan 44, to Memo SW for CofS, 13 Jan 44, sub: Biological Warfare. Cited in BW Research in the U.S., pp. 28–30.

[18] Soon after, almost all BW research was conducted by the military and by OSRD. James Phinney Baxter, 3rd, *Scientists Against Time* (Boston: Little, Brown, and Company, 1946), p. 269.

velopment on BW in the United States remained under the direction of this committee until October 1945 when the War Department dissolved it and transferred its functions to the New Developments Division.[19]

The Special Projects Division

The CWS had maintained an element variously known as the "Medical Research Division," and "Special Assignments Branch" at Edgewood ever since August 1941, principally for studying biological warfare, acquiring the staff to conduct it, and in assigning BW research projects to NDRC agencies. It was not until 18 January 1944, however, that a separate organization, the Special Projects Division, was established in the Office of the Chief, Chemical Warfare Service, to administer the biological warfare program.

By January 1944 the CWS had already begun operations at Camp Detrick and at the field test station on Horn Island in Mississippi Sound, and was constructing the Granite Peak test installation, adjacent to Dugway Proving Ground, Utah, and the Vigo plant in Indiana.

The Special Projects Division was to develop measures for defense and retaliation against BW, to produce or procure the necessary material, to collect and evaluate intelligence on enemy activity, to maintain liaison with other military and civilian organizations concerned with biological warfare here and abroad, to prepare training publications and conduct instruction in biological warfare, and to supply technical advice to the armed forces.[20] The division had an immense task and had to do the work hurriedly because of the urgency of the problem as understood at that time. Construction, research, and instruction were necessarily simultaneous operations at all installations of the Special Projects Division.

In April 1943, a little more than two weeks after the Army began construction at Detrick Field, Camp Detrick was formally activated.[21] The Horn Island installation, with its 2,000 acres of sand dunes and scrub, began operations in October 1943. These were restricted to preliminary small-scale experiments because the island was only ten miles away from the mainland and because it was belatedly discovered that for two-thirds of the year the prevailing winds blew toward the mainland.

[19] Memo, Robert P. Patterson, SW, for General Marshall, 30 Oct 45. Cited in BW Research in the U.S., pp. 30, 494–95.

[20] BW Research in the U.S., pp. 51–52.

[21] BW Research in the U.S., pp. 36–39, 88–92.

BIOLOGICAL WARFARE TEST STATION, *Granite Peak, Utah.*

In view of the limitations of Horn Island, the principal BW test station became Granite Peak, activated in June 1944, with test operations commencing shortly thereafter. The isolated terrain at Granite Peak, thirty-five miles from the military post at Dugway Proving Ground, made it a relatively safe area for testing living biological agents, and there all the major field studies were carried out.[22]

The Vigo plant was a converted Ordnance installation south of Terre Haute, Ind. The CWS took over the plant in May 1944. Scientists and engineers installed equipment for large-scale production of a harmless bacterium, *Bacillus globigii*, based on preliminary pilot plant studies made at Camp Detrick. The CWS did not intend to produce pathogenic agents until the plant had been thoroughly tested for safety and until employees could be trained to a high degree of efficiency. These operations were still in progress at the end of the war.[23]

To a greater degree, perhaps, than in any of the other CWS research programs, the one for biological warfare was a joint service undertaking. The Navy, for example, provided almost a quarter of the technical staff required at Camp Detrick and other test installations, drawing them principally from the Navy Bureau of Medicine and Surgery and the Bureau

[22] BW Research in the U.S., pp. 40–45, 92–94.
[23] BW Research in the U.S., pp. 46–50, 94–97.

of Ordnance. In addition the Navy Department maintained an independent research unit at the University of California, although its work was co-ordinated with that being done at Detrick and elsewhere in university laboratories.[24]

The Office of The Surgeon General, a participant in all matters concerning BW, had representatives from the outset on each of the committees formed to study the problems and conduct of BW research. At the direction of the War Research Service, the Office of The Surgeon General and officers of the Medical Corps initiated antibiological warfare programs in the continental United States, in Hawaii, in the Canal Zone, and in the theaters of operation. The SGO also assigned trained sanitary engineers to protect essential industrial plants against sabotage. In co-operation with the CWS and the Corps of Engineers it developed procedures for protecting water supplies of municipalities and Army posts. In co-operation with the Provost Marshal General, the Veterinary Corps inspected all meat and dairy products used by the Army. All food, beverage plants, and water supplies in the Hawaiian Department were inspected regularly. Studies were made of the possible dangers of sabotage of medical supplies while in production, in storage, or being distributed, and control methods were devised for use by the drug industry to prevent sabotage.[25]

When the War Department assumed responsibility for the BW program, it directed The Surgeon General to co-operate with Chemical Warfare Service in all defensive aspects of the project. It soon became apparent that the line between offensive and defensive BW research could seldom be distinguished. Further, The Surgeon General felt that it would not be proper or desirable for the Medical Department to accept responsibility for any phase of BW research.[26] The CWS therefore assumed both aspects of this research. While The Surgeon General was thus relieved of responsibility for the technical program, he designated a liaison officer to keep him informed of its progress and he made available scientists of his Preventive Medicine Service, Veterinary Division, and Medical Consultants Division. At the same time, The Surgeon General set up a BW commit-

[24] BW Research in the U.S., pp. 60–65.

[25] Ltr, SG to G. W. Merck, WRS, 1 Apr 44, sub: Surgeon General Functions. Cited in BW Research in the U.S., p. 66.

[26] (1) Ltr, SGO to C CWS, 25 Jan 44, sub: Liaison Officer at Camp Detrick, Md. SGO 020. (2) Memo, Col K. R. Lundeberg, MC, OSG, for Maj Gen Kirk, Maj Gen Lull, Brig Gen Hillman, and Brig Gen Simmons, 30 Mar 44. (3) Memo, C CWS for C SPD, 5 Apr 44, sub: Medical Research and Development Activities of the Special Projects Division. SPD 321. All cited in BW Research in U.S., pp. 67–69.

tee in his office to advise him on BW policy and procedure and to direct the procurement and storage of all biological supplies developed by the Special Projects Division for protecting personnel against biological agents.

At the peak of operations the Special Projects Division was the largest single research element in the Chemical Warfare Service and vied only with the Manhattan Project—at times successfully—in securing certain types of scientists. It was so large, in fact, that it was extremely difficult at times to control the numerous research divisions at Camp Detrick. The best known demonstration of this unwieldiness was in the independent and original achievement of workers in two different divisions, each of which was able to claim legitimate credit for isolating, for the first time, the Type A botulinum toxin. In August 1945, at maximum strength, the division had 396 Army officers, 2,466 Army enlisted men, 124 Navy officers, 844 Navy enlisted men, and 206 civilians.[27]

Keeping It Secret

From the very beginning responsible officials maintained the strictest secrecy in this country, Canada, and England concerning the fact that work was being done in BW. They took stringent security measures not only to prevent the enemy from obtaining information, but also to keep the public and the armed forces from becoming unduly alarmed over the possibility of BW.

Security and Safety

Because they were set up as classified exempt stations, Camp Detrick and other BW installations took elaborate precautions to conceal their purpose. The professional background of employees could not be revealed, no person receiving "special procedures" (as the vaccination routines were called) might donate blood to the Red Cross, and the nature of materials and stores procured for the installation was disguised.

An important phase of security operations at Camp Detrick involved the nearby town of Frederick. Despite all efforts, as was reported in a security survey made in the town, anyone who really wanted to find out

[27] By comparison, after four years the British BW group under Dr. Paul Fildes at Porton numbered 45, comprising 15 officers and civilians (including 4 officers supplied by Camp Detrick), 20 enlisted technicians, and 10 female helpers. See Report on Visit of Lt Col Oram C. Woolpert (Chief of Tech Dept CD) to ETO, 22 May–2 Jul 44, p. 2. Cited in BW Research in the U.S., pp. 75, 479–81.

that BW research was being conducted at Detrick could easily have done so through the camp construction workers who lived in Frederick and the post employees who visited its restaurants, stores, and theaters, or by studying the type of materials purchased for the post in Frederick or shipped in by rail. Above all, the physical layout of the camp, with its smoke stacks and special sewage arrangements, was informative, and clearly visible from Braddock Heights, a nearby prominence. The security officer nevertheless found that townspeople in general considered Detrick only a secret chemical warfare installation and either showed little interest or pointedly refrained from expressing curiosity about it.[28]

All research at Detrick had to be geared to considerations of safety in order to minimize the danger of exposure to pathogenic organisms. The creation of a Safety Division was one of the first steps in the organization of the center, its functions equally divided between a biological protection group and operational safety control groups. The first element was made responsible for close inspection of employees, first aid, and immunization; the second for inspection of operations in the pilot plants and laboratories, and for providing methods of detecting, decontaminating, and treating biological materials and wastes which might escape and infect the people at Camp Detrick or in the surrounding community. Many of the practices, testing devices, and techniques developed by the Safety Division for research and development operations at Camp Detrick, some of them wholly new and others on a scale never attempted previously, have since been applied to industry and medicine.[29]

Intelligence

The extraordinary effectiveness of American security and counterintelligence policies was revealed after the fall of Germany and Japan. The security measures of Germany and Japan made their capabilities almost equally inscrutable, a matter of concern to the United States since to a degree the direction of the CWS's BW program depended on knowledge of enemy intentions.

When the War Department assumed control of BW research, the CWS's Special Projects Division took charge of intelligence. It sent War Department directives to all theaters and commands alerting them to BW, describing defensive measures against possible sabotage, and recommend-

[28] BW Research in the U.S., pp. 127–29.
[29] BW Research in the U.S., pp. 151–52, 159–67.

ing appointment of staff BW officers. In the European Theater of Operations, for example, the Chief Chemical Officer prepared BW plans and directives, supervised BW training, maintained liaison with British BW authorities in the theater, and co-operated with the Chief Surgeon and Assistant Chief of Staff, G-2. The period of greatest apprehension occurred in the early months of 1944 when planners feared that, as the allied offensive across both oceans began to move forward, the enemy in the face of his steady deterioration might "in desperation resort to biological warfare." [30] Largely to meet this threat, the service established a BW school at Camp Detrick, with the first class held in February 1944. After attending the school, the chief of CWS intelligence went overseas to alert CWS officers in the Middle East and North Africa theaters. Other graduates went from Detrick to the China-Burma-India and Pacific theaters to indoctrinate G-2, ONI, and medical officers stationed there. The Army attached trained BW officers to all major military operations in Europe and in the Pacific. Chiefs of the Joint Intelligence Collecting Agency in the North African, Middle East, and China-Burma-India theaters were given BW instructions, as were military attachés in New Zealand, Canada, Sweden, Spain, Portugal, South Africa, China, and Australia. Also CWS members of the ASF matériel collecting teams, previously briefed on what BW matériel to look for, arrived in the European, North Africa, South Pacific, Southwest Pacific, Central Pacific, and China-Burma-India theaters in the summer of 1944. All BW intelligence flowing from these far-flung sources, as well as from service and central intelligence agencies, was reported in the voluminous Special Projects Periodic Intelligence Reports.

On neither the intelligence nor instructional level were British efforts as strenuous as those of the United States. They had no school similar to that at Camp Detrick, nor did they train special BW officers. Then, too, they had no counterpart to the United States BW intelligence network. They gave instruction in BW only to the highest echelons of command, whereas the CWS prepared directives for all those above troop level in the Chemical Warfare Service and in American medical and intelligence services.[31]

[30] (1) Ltr, TAG to CinC SWPA and CG's TofOpns, Eastern and Caribbean Defense Comds, and Alaska Dept, 14 Feb 44, sub: Biological Warfare. AG 381 (9 Feb 44) OB-S-B-M. (2) Ltr, TAG to CG's TofOpns, 28 Mar 44, sub: Defense Against Sabotage Methods of Biological Warfare in the Theaters of Operations. AG 381 (24 Feb 44) OB-S-E-4. Both cited in BW Research in the U.S., p. 134.

[31] Rpt, Visit of Lt Col Woolpert to ETO, 22 May-2 Jul 44. Cited in BW Research in the U.S., p. 145.

The findings of the ALSOS Mission provided the first indication that the truth about German BW activities was considerably at variance with earlier intelligence reports. False reports of German intentions to resort to germ warfare had unquestionably been spread as a psychological warfare weapon. In spite of the first reports of the mission, tension was not relaxed until early in 1945, when it was generally agreed that it was too late for Germany to use BW as a tactical weapon against Allied forces.

The comprehensive report of September 1945 prepared by the BW team with the ALSOS Mission[32] revealed that BW research in Germany had been aimed at devising defensive measures against possible Allied use of biological agents and specifically against the sabotage efforts of guerrilla fighters that menaced the German Army in Poland and Russia. Among the biological agents reportedly used by guerillas against German troops in the Eastern theater were typhoid bacilli, botulinum toxin, typhus, dysentery, glanders, cholera, anthrax, and paratyphoid.

Investigators examined more than seventy sites in Europe where Germans had conducted medical research. Nazi defensive measures consisted mainly in alerting agriculture, veterinary, and public health officials to the dangers of biological attack. They took their only large-scale defensive measure in 1942, when, after hearing that Russian troops had been immunized against plague, they sent one million doses of plague vaccine to the Stalingrad front. The files of German intelligence gave extensive information on Russian and Polish BW efforts and were fairly complete on French research. But they contained no reliable information from the United States or the United Kingdom after 1942, a tribute to security precautions. For example, in German intelligence files the ALSOS mission found a report stating that the United States had a large BW agent production plant at Huntsville Arsenal, Ala., and that the U.S. BW program was headed by an outstanding microbiologist, Col. Harry Lebkicher. The facts were that Huntsville Arsenal handled only chemical warfare, never biological warfare operations, and that Colonel Lebkicher was not a biologist and never had an assignment in BW—he was commanding officer of the Chicago Chemical Warfare Procurement District.[33]

Japanese activities were better organized and more comprehensive than

[32] Its members were J. M. Barnes, RAMC; C. Henze, MC, AUS; W. J. Cromartie, MC, AUS; and J. W. Hofer, MC, USNR.

[33] (1) Int Rpt B–C–H–H–305, Mil Int Serv, ALSOS Mission, 12 Sep 45, pp. 82–88. (2) Memo, C Int Br SPD for Consultant to SW, 20 Aug 45, sub: Final Resume of German BW Activities. Both cited in BW Research in the U.S., p. 140.

those of Germany. Japan appears to have started biological warfare studies as early as 1936, with the principal wartime research centered in a Defense Intelligence Institute, near Harbin in Manchuria, where 2,500 people were employed at the peak of operations. The institute developed munitions for glanders and anthrax. Allied intelligence seems to have been accurate in its accounts of a Japanese bacillus bomb, its name literally translated as "disease frozen germs," and experiments seem to have been made, as reported, in the dissemination of typhoid, diphtheria, and cholera. The Japanese denied, however, that the more than 9,000 paper balloons they constructed, of which a number, more than thirty feet in diameter and capable of lifting sixty-five pounds, sailed across the Pacific to the west coast and Canada early in 1945, were intended for BW attack. The Japanese claimed that the balloons, which actually contained explosive and incendiary material, had been sent in reprisal for the Doolittle raid.[34]

Defense Against Biological Attack

The CWS and SGO investigated special physical, chemical, and medical measures to protect the armed forces and civilian population against biological warfare. In this effort, basic defensive measures were first developed to safeguard the thousands of workers engaged in the Special Projects Division laboratories. Techniques had to be devised for detecting, sampling, screening, and identifying a great variety of living organisms and their toxic products. Equipment had to be designed, constructed, and installed to handle processes never before carried out. Protective clothing, masks, and equipment had to be developed for use in the laboratories, plant areas, and field test stations. Many of these primary steps in defense on behalf of SPD employees were taken to provide the basis for the development of protective measures for the soldier in combat should biological warfare become an actuality.[35]

Detection and Identification of Biological Agents

In war an unusual outbreak of disease would probably be the first indication that BW agents were being employed. Troops would immediately need a sampling device to detect organisms. The CWS therefore devised

[34] (1) Lt Col Arvo T. Thompson, VC, Report on Japanese Biological Warfare (BW) Activities, 31 May 46, pp. i–iii, 6–7. (2) Inf & Int Ltr, 6, ASF POA, 21 May 45. Tech Lib, Camp Detrick. Both cited in BW Research in the U.S., pp. 140–41.

[35] BW Research in the U.S., *passim.*

a sampling kit to detect biological agents in the field. It contained cotton impinger and liquid impinger apparatus for air sampling; cotton swabs, syringes, and pipettes for material sampling; and means of refrigerating the materials collected. Contaminated air and materials collected by these devices would then be taken to the field or base laboratory for identification.[36]

As in standard hospital practice, identification of micro-organisms could sometimes be made by direct or microscopic examination of sample organisms which were grown on agar plates, but the most reliable detection test for most biological agents involved animal inoculation and response. By inoculating animals scientists could detect most pathogenic organisms and their toxins. Examination by smear would then be possible, using the exudate from wounds or lesions or with sputum, feces, blood, or urine. This evidence could then be corroborated by means of blood chemistry analysis, blood cell counts, and urinalysis. As the infection declined or recovery was effected, detection would also become possible through the appearance and identification of antibodies in the blood. These could be demonstrated by agglutination reactions, toxin neutralization, or virus neutralization. With proper identification thus made, countermeasures against the particular agent or agents become possible.

Biological and Chemical Protection

During the war, Camp Detrick and university laboratories investigated biological, chemical, and mechanical means of protecting troops against potential biological warfare agents. While soap and water afforded elementary protection in uncomplicated circumstances, the agents and vehicles in biological warfare would have required somewhat more complex protection. At Camp Detrick biological protection against micro-organisms included the use of vaccines, toxoids, and immune sera, as well as penicillin and streptomycin. Disinfectants and antiseptics, standard CWS decontaminating agents, and the new chemotherapeutic agents like the sulfa drugs provided chemical protection. Mechanical and physical protection was possible with special leakproof masks and protective clothing which would exclude organisms, and the employment of heat (as in incineration or the use of the autoclave), desiccation, starvation, sunlight, osmotic pressure, and filtration for the removal, inhibition, or destruction of organisms. The CWS considered it feasible to protect large groups of

[36] BW Research in the U.S., pp. 159–62.

people by special adaptation of the gasproof shelter and collective protector, through the maintenance of strict sanitary discipline, the application of public health principles, and by means of immunization.

While no immunological protection was possible in gas warfare, considerable protection could be conferred in biological warfare by protective equipment and through increased body resistance. Since the best means of increasing resistance to specific disease organisms was by immunization through the administration of vaccines, the CWS devoted a major part of the BW program to the development and production of new vaccines and toxoids. Before World War II, scientists had prepared vaccines for use against such diseases as smallpox, yellow fever, cholera, typhoid and paratyphoid fevers, diphtheria, tetanus, plague, typhus fever, and influenza. Of these typhoid, diphtheria, tetanus, smallpox, and yellow fever vaccines appear to have been exceptionally effective but the others had limited value against the diseases as they occurred naturally, and would probably have had considerably less protective value against an attack employing high concentrations of the disease agent.[37]

Among the accomplishments in biological protection made public after the war may be mentioned new influenza vaccines and the development of effective toxoids against Types A and B botulinum toxin. For the protection of livestock and domestic fowl—exceedingly vulnerable targets in the event of biological warfare—researchers discovered means for mass production of highly effective vaccines for rinderpest, an animal disease, and for Newcastle disease and fowl plague, domestic fowl diseases.[38]

In addition to the vaccines, a new means of biological protection for the individual was made possible by the recently developed antibiotic agents referred to above. While usually employed in treatment, they could also be used prophylactically for short periods of time and, it was believed, they might have an advantage over vaccines in conferring protection immediately after administration. On the basis of wartime studies, there was evidence that penicillin might be effective in treating human anthrax and that streptomycin was effective in treating tularemia.

[37] BW Research in the U.S., pp. 152–58.

[38] (1) H. Reames *et al.*, "Studies on Botulinum Toxoids, Types A and B: Immunization of Man," *Journal of Immunology*, 55 (1947). (2) M. W. Hale and R. V. L. Walker, "Rinderpest XIII, The Production of Rinderpest Vaccine from an Attenuated Strain of Virus," *American Journal of Veterinary Research*, 7 (1946), 199–211. (3) C. A. Brandly *et al.*, "Immunization of Chickens Against Newcastle Disease," *American Journal of Veterinary Research*, 7 (1946), 307–32. (4) C. A. Brandly *et al.*, "Newcastle Disease and Fowl Plague Investigations in the War Research Program," *Journal of the American Veterinary Medical Association*, 108 (1946), 369–70.

In the realm of chemical protection, it appeared that the chemotherapeutic agent, sulfadiazine, might be one of the principal means of attacking the organisms causing glanders and melioidosis once they invaded the body. Other substances providing varying degrees of chemical protection were found among the common antiseptics and disinfectants. The chemical which most nearly met the conditions of an ideal germicide for military and civilian purposes was ordinary calcium hypochlorite, or bleach, the same material used for neutralizing mustard gas. It was effective against almost all micro-organisms. Its action was rapid, large quantities were available, it was not hazardous to use, it was easily inactivated, and it could be used in a variety of apparatus. Similarly, decontaminating agent, noncorrosive, or DANC, another demustardizing agent, was effective in BW for disinfecting the metal surfaces of equipment and instruments. Methyl bromide, found in the standard Quartermaster delousing kit, proved an effective sterilizer, and carboxide, the Navy fumigating agent, sterilized both clothing and equipment. Formaldehyde when dispersed with steam under pressure in enclosed spaces also made a good decontaminating agent, and the CWS M2 smoke generator and commercial spray apparatus could be used to vaporize a formalin-water mixture for the sterilization of air. Finally, certain glycols in the form of aerosol mists were satisfactory for use with the standard collective protector installed in a modified gasproof shelter.

Protective Masks and Clothing

Where, under combat conditions, there was danger of biological warfare and no way of knowing what micro-organisms an enemy might use, the individual soldier would, as in gas warfare, have to rely on his mask and special protective clothing. One of the most pressing problems of CWS research, therefore, was to devise truly effective leakproof combat and service masks.

A minute degree of leakage could be tolerated in the standard mask under gas attack. But biological agents are not molecular particles like war gases. They are suspensions of solids in the air, and a few disease micro-organisms entering the facepiece might produce a casualty. The mask for biological warfare, therefore, had to be at least an estimated 1,000,000 times more efficient than the standard service gas mask.[39]

[39] BW Research in the U.S., p. 177.

Technicians attained near zero leakage by modifying the M5 combat mask and adding to it a special leakproof headpiece made of butyl coated airplane cloth. This impermeable headpiece, covering the entire head and the facepiece of the mask except for the eyepieces and canister, reduced peripheral leakage of the mask facepiece and provided a dead air space around the outlet valve of the mask, thus affording a high degree of protection at that point. The slight positive pressure exerted within the headpiece by the trapped exhaled air made entry of air impossible except through the canister. The weight of this BW mask, including facepiece, headpiece, canister, and carrier was 3.2 pounds, making it a practicable as well as highly effective unit of protection in the event of BW combat. Further development resulted in a leakproof service mask weighing 2.3 pounds, with a headpiece of butyl coated nylon, improved eyelenses permitting better vision, and with the canister fitted inside the headpiece. Although both of these combat and service masks were considered satisfactory, improvements were still being made by V-J Day.[40]

The special protective clothing designed for laboratory workers at Camp Detrick was not considered practicable for combat troops. Almost complete physical protection was achieved with the impermeable coverall made of wind-resistant, water-repellent Oxford cotton cloth. But this very impermeability, because it prevented the perspiration from escaping, also put limits on the length of time it could be worn and the degree of strenuous exercise possible. For particularly hazardous laboratory operations, a special ventilated suit was designed which provided absolute protection. This was a one-piece garment of two layers of nylon cloth bonded together with neoprene, and with gloves and shoes of rubber cemented to the fabric. Air introduced into the back of the suit by hose enabled the wearer to work in the attire.

For combat troops, the standard two-piece, permeable, herringbone twill uniform, when treated by the CWS aqueous impregnating process, was considered the best available protective clothing which could be worn in comfort. Tests indicated that the suit would probably exclude half the number of organisms to which the body would be exposed without the clothing. The addition of special ankle-length underwear under the suit increased the degree of protection, probably raising the exclusion of organisms to almost 90 percent,[41] provided that sleeves of the uniform were

[40] BW Research in the U.S., pp. 177–84.
[41] BW Research in the U.S., pp. 184–86.

tied tightly at the wrists, pants legs fastened to the ankles or stuffed inside combat shoes, and all other openings carefully secured.

The CC-2 impregnite used in protective clothing, researchers found, had considerable sporocidal properties. The standard aqueous impregnation process appeared to give the most powerful bactericidal and sporocidal properties to the clothing, although relatively high atmospheric humidity was required for the most efficient action. On the other hand, M5 anti-mustard ointment was found to have negligible bactericidal and sporocidal properties when applied as skin protection. Instead, gloves of Oxford cotton cloth seemed reasonably efficient for the purpose, and, for prolonged wearing, more comfortable than medical rubber gloves.[42]

The Achievement in Biological Warfare Research

A brief résumé of this country's BW achievements, published on 3 January 1946 and based on a comprehensive report by Mr. Merck to the Secretary of War, was the first War Department release informing the general public of the fact that the Army and Navy had been engaged in the study of biological warfare.[43] Among the accomplishments of the BW research and development reported then and later were: (1) fundamental contributions had been made regarding nutrition and conditions of growth of micro-organisms, as well as safe procedures for their quantity production; (2) methods had been developed for accurate detection of small numbers of minute quantities of micro-organisms; (3) many contributions were made to the knowledge of control of airborne diseases; (4) significant contributions had been made to the knowledge concerning the development of immunity against certain infectious diseases of humans and animals; (5) important advances were achieved in the treatment of certain infectious diseases of humans and animals; (6) important information had been secured on the production and control of certain diseases in plants and on the effectiveness of over 1,000 different chemical agents on a variety of plant life.

Between October 1945 and June 1947 the CWS published a total of 156 scientific and technical papers based upon wartime research and development at Camp Detrick and presented 28 other papers at scientific meetings.

[42] BW Research in the U.S., pp. 187–91.

[43] Some of the material of this report appeared in *Military Surgeon,* 98 (1946), 237–42, and in *Science,* 103 (31 May 46), 662–63. See also George W. Merck, "Peacetime Implications of Biological Warfare," *Chemical and Engineering News,* 24 (25 May 46), 1346–49.

In evaluating the magnitude of American BW achievement it should be remembered that the United States began operations with British and Canadian experience to draw on and with the added advantages over these allies of almost unlimited funds and personnel and with the finest facilities obtainable. There was also some justice in the remark reported by the chief of technical operations at Camp Detrick, after a visit to his British counterpart in 1944, that there was "a certain amount of duplication of effort in the several countries; that we in the States [did] not take full account of their fundamental studies and . . . attacked *de novo* problems which they had solved satisfactorily."[44]

GEORGE W. MERCK, *Special Consultant to the Secretary of War, visiting Camp Detrick, Maryland. Col. Joseph D. Sears, left.*

It could not, perhaps, have been otherwise. Despite its kinship with public health medicine and preventive medicine, biological warfare research and development, on the scale undertaken in World War II, was literally something new under the sun. Both the United States and its allies had to work by empirical methods, without precedent, and with all possible haste. America had to prepare to defend itself, and to have an offensive weapon for retaliation.

A series of implications drawn from American experience in BW research was reported in 1946 in a public document prepared by former officials of the United States Biological Warfare Committee.[45] There it was asserted that the development of agents for biological warfare was possible in many countries, large and small, without vast expenditures of money or the construction of large-scale production facilities. It was quite

[44] Rpt, Visit of Lt Col Woolpert to ETO, 22 May–2 Jul 44, p. 3. Cited in BW Research in the U.S., pp. 479–81.

[45] G. W. Merck, E. B. Fred, I. L. Baldwin, and W. B. Sarles, "Implications of Biological Warfare," *The United States and the United Nations Report Series No. 5, The International Control of Atomic Enery,* Department of State, Pub. 2661 (Washington, 1946) pp. 65–71.

probable that research directed toward enhancing the virulence of known pathogens would result in the production of varieties much more virulent than those already known. Finally, unlike other fields, it would be extremely difficult to control research and development work in biological warfare.

Biological agents, like toxic agents, were not used in the war, but the money spent by the United States on BW, like that spent on CW, was not thrown away. Rather, the expenditures should be viewed in the light of the harm that might have come to an unprepared America through a sneak BW attack.

CHAPTER VI

Chemical Mortars and Shells

The 4.2-Inch Chemical Mortar

Weapons available to American ground troops for delivering toxic agents included Livens projectors, grenades, land mines, mortars, rockets, and artillery shells. If gas warfare had broken out, the burden would have fallen chiefly on the 4.2-inch chemical mortars of CWS mortar battalions.

The 4.2-inch mortar descended from the old Stokes mortar of the British Army. Britain invented the Stokes in World War I to overcome the disadvantages of gas cloud attacks. Gas clouds could be tremendously effective under the proper conditions, but they required considerable labor, were wholly dependent upon the weather, could only be used with a few gases, and, by their color and odor, sometimes warned the enemy. The Stokes had a smoothbore barrel and therefore could not fire shells with pin-point accuracy. On the other hand, it had certain advantages. Troops could easily move it and fire shells at the rapid rate of twenty a minute. Each shell held more than two quarts of toxic agent. Because of these factors a mortar could suddenly overwhelm an enemy position with a large amount of poison gas.[1]

The First Gas Regiment of the CWS obtained Stokes mortars from the British in 1918, and employed them along the western front. In July 1918 the Army contracted with American firms for the manufacture of these mortars. More than 400 were turned out but they did not reach France in time for battle.

[1] Fries and West, *Chemical Warfare*, pp. 16–18. (2) For the early use of the Stokes mortar see: Foulkes, *"Gas!" The Story of the Special Brigade*, pp. 109–11.

STOKES MORTAR FIRING GAS SHELLS, *World War I.*

The CWS found the Stokes mortar a versatile, useful weapon, and in the early 1920's set out to lengthen its range. The objective, as laid down by General Fries, was to double the World War I range of 1,100 yards.[2] Early experiments showed that heavy powder charges could hurl the shell only a few hundred yards beyond the normal range. This was dangerous since the higher pressure within the mortar at the instant of explosion could burst the barrel. The designers attached fins to the shell, enabling it to fly through the air like a dart, and shot it 2,600 yards. But the shock from the exploding propellant generally damaged the fins, and the shell's flight was short and erratic. In 1924 Captain McBride and Dr. G. S. Maxwell rifled several barrels with varying pitches and numbers of grooves. During machining operations metal was gouged out of the bore, increasing its diameter from four to four and two-tenths inches between lands. This marked the end of the old smoothbore Stokes mortar, and the beginning of the new 4.2-inch chemical mortar. On 7 June 1924 one of the

[2] (1) A. E. Nissen, A. A. Gandy, and A. L. Hodges, 4.2-Inch Chemical Mortar. EAMD 26, 17 Mar 27. (2) Maj. Gen. Amos A. Fries, "General Fries," *Armed Forces Chemical Journal,* 1 (October 1946), 12, 51.

experimental barrels sent three shells through the air on accurate, spin-stabilized flights of almost 2,300 yards.

Adoption of a rifled barrel made it necessary for engineers to redesign each component of the mortar, from baseplate to shell fuze. World War I shells had had an allways fuze to make certain that the tumbling shell would explode no matter whether it landed on its base, side, or nose. Fuzes of this type could not be used in a spinning shell since centrifugal force would activate the fuze and cause the shell to burst as it left the muzzle of the mortar. After considerable experimentation, engineers developed a safe, dependable fuze that could be set for impact or time.

Something had to be done to prevent liquid fillings, such as mustard or phosgene, from surging around the inside of the shell, unbalancing it and causing it to tumble and yaw in flight. This characteristic had not mattered with the Stokes mortar since its shells had tumbled anyway, but it affected the accuracy and range of the rifled mortar. Technicians solved this problem by fastening vanes inside the shell to swirl the fillings as the shell spun through the air.

To seal the bore against loss of explosion gases, and to force the shell to rotate as it sped up the barrel, the men had to devise a driving mechanism for the base of the projectile. This consisted of two round plates, one of brass and one of steel, the brass disk designed so that its edge could be forced outward by pressure. When the powder exploded, gas pressure rammed the steel plate up against the softer brass plate, forcing its edge out and into the grooves, sealing the gases in, and forcing the shell to spiral out of the barrel.

For the baseplate of the Stokes mortar it had been feasible to have a steel cup, bolted to an oak plank. But recoil from the new 4.2-inch barrel soon pounded this type of baseplate into splinters, and a forged steel baseplate had to be produced. Finally in 1928, after several years of experimentation, model M1 4.2-inch chemical mortar was ready for service.[3]

During the next decade CWS engineers put considerable thought into improving the standard model. The practice of digging an emplacement, which took time and reduced the mobility of the mortar, was abandoned

[3] (1) Ltr, Maj Gen Amos A. Fries to TAG, 17 Apr 28, sub: Adoption as to Type, with inds. CWS 400.114/280. (2) 4.2-Inch Chemical Mortar, a monograph in series, History of Research and Development of the CWS in World War II. (3) An excellent review of all phases of mortar development from World War I to 1945, is: George A. Miller, "The Development of the 4.2-Inch Chemical Mortar," *Armed Forces Chemical Journal*, III (October 1948), 33–42; III (January 1949) 35–42.

and the base was placed directly on the ground. The two legged support inherited from the Stokes mortar was improved and retained for a time, but it proved to be so awkward that it gave way to a single leg. Engineers then found it necessary to place connecting rods between the baseplate and barrel support to keep the recoil from forcing base and support apart. The barrels, hitherto obtained from old Stokes mortars, were made specifically for the new model from seamless drawn-nickel steel tubing. A spring shock absorber was placed on the barrel to prevent the force of recoil from breaking the connection between the support and the barrel. At last after seven years of work the CWS completed a greatly improved mortar, model M1A1, with a range of 2,400 yards. This mortar was in the hands of chemical troops at the time of Pearl Harbor.[4]

Increasing the Range in World War II

The next step in the development of the mortar came about as a result of an addition to the mission of CWS troops. Up to the time of America's entrance into the war, the mortar had been considered as a weapon for firing toxic agents, smoke, and incendiaries at the enemy. In April 1942 General Porter asked the Services of Supply for permission to use high explosive ammunition in the mortar. Chemical troops had fired HE in World War I, and if allowed to do the same in World War II it would broaden their usefulness in the theaters of operation. The SOS gave its consent, thereby again giving the CWS impetus in lengthening the range.

The mortar had been developed under the prewar doctrine that chemical shells would be employed only within a range of 2,400 yards. This concept did not apply to HE, and the CWS set about increasing this distance before the mortars saw action. Engineers could have lengthened the range by redesigning parts of the mortar, but such a step would have taken time. The quickest way was to use more powder. When tests demonstrated that 50 percent more powder hurled the projectile an additional 800 yards, bringing the total distance up to 3,200 yards, a larger charge was adopted. The higher explosion pressure imposed more strain on the barrel and baseplate than they had been designed for. To prevent accidents the service adopted a tougher barrel and baseplate. To prevent mortar squads from using the old barrel and perhaps blowing themselves up the

[4] (1) CWTC Item TB, 21 Feb 35. (2) CWTC Item 485, Standardization of Barrel, 4.2-Inch Chemical Mortar, M2, 31 Mar 42. (3) TM 3-320, 15 Oct 42, with changes 1 to 5.

CWS designated all mortars with the new barrel as model M2. The CWS carried the M2 into all theaters and some were still in action at the end of the war.[5]

The 4.2-inch mortar first saw action in the taking of Sicily in the summer of 1943. Mortar squads were among the first waves of troops to hit the beach, and they went into action a few minutes after landing. During the thirty-eight day campaign they shot 35,000 rounds of ammunition in crash concentration, harassing, interdictory, and counterbattery fire, and in tactical smoke screening missions. The mortar made an excellent impression on commanders of infantry, ranger, armored, and airborne units. Thereafter there was no question that the CWS had taken the right course in turning the chemical mortar into a HE delivering weapon.[6]

After troops tried out mortars in Europe, they began calling for a longer range. Back in the United States the CWS had already anticipated the demand and had succeeded in adding another thousand yards to the flight of mortar shells. It had achieved the increase by changing the form of the propellant so that it burned slowly, gave off gas more evenly, and thereby became more efficient. Lt. Arthur R. T. Denues had experimented with the propellant, trying different shapes, arrangements, and types, and had finally found that with disks of powder of a certain thickness, the range depended upon the number of disks. The minimum charge, which lobbed the shell only 340 yards, could be lengthened to 4,400 yards simply by adding more disks. The maximum gas pressure did not become excessive, and there was no disturbance in the ballistics of liquid filled shells. The disks were cut square, with a hole in the center to allow the disk to slip on the cartridge container. Sufficient disks, sewn together in bundles of different thickness, were placed on each shell before shipment to give a range of 4,397 yards. Before the shell was fired, the mortar squad could remove one or more disks to shorten the range.[7]

[5] (1) Interv, Hist Off with Theodore R. Paulson, 16 Nov 56. (2) CWTC Item 636, Standardization of M5A1 Propelling Charge for 4.2-Inch Chemical Mortar, 12 Jan 43. (3) CWTC Item 673, Standardization of Charge, Propelling, 4.2-Inch Chemical Mortar, M5A1. (4) CWTC Item 727, Standardization of Baseplate, 4.2-Inch Chemical Mortar, M2A1, 11 Jun 43. (5) Baum, Columbia University Chemical Warfare Service Laboratories. (6) CWTC Item 564, Redesignation and Reclassification of 4.2-Inch Chemical Mortars and Equipment, 29 Sep 42. (7) TM 3-320, Jun 45.

[6] *The Chemical Warfare Service in World War II* (New York: Reinhold Publishing Corp., 1948), pp. 127-28.

[7] (1) Lt A. R. T. Denues, Preliminary Investigations and Engineering Tests to Develop Increased Range for the 4.2-Inch Chemical Mortar by Means Adapted to Immediate Field Use. TDMR 549, 17 Feb 43. (2) CWTC Item 673.

Notwithstanding that the range of the mortar had almost doubled by 1944, troops in the field were still not satisfied. They wanted the weapon to hit targets 5,000 or more yards away. One means of accomplishing this was to devise a jet accelerator that would fit on the base of a shell and give it a boost after it left the barrel. The CWS started work on such a device, but soon canceled the project after a survey showed that development would take too long, and that men with the know-how could not be spared from other mortar projects.[8]

Two other courses lay open to the CWS, a long-term project to completely redesign the mortar from baseplate to standard, and a short project—which might or might not work—of again modifying the propellant. Experiments with the propellant began after calculations and preliminary experiments indicated that the velocity of the shell could be increased 100 feet per second and the range jumped to more than 5,000 yards if the chamber volume of the mortar and the weight of powder were doubled. Engineers set up an experimental mortar and made test firings, but to their surprise the shells had an unexpectedly short range. They carefully checked all possible sources of error and at last discovered that the high pressure from the explosion had deformed the rotating disk on the base of the shell and this had increased the air resistance. Development of a new rotating mechanism proved to be the major task in extending the range, but when the job was finished the mortar shell carried distances of 5,600 yards in firings at Edgewood in June 1945. These results obtained in the shop and on the test field occurred too late in the war to be transmitted to the battlefield.[9]

Regardless of demands for longer ranges, a complete redesign of the mortar was necessary by 1944. By this time both the M1A1 and M2 had been used extensively, particularly in mountainous regions where artillery found it difficult or impossible to operate. The terrain in which mortars operated in Italy and the Southwest Pacific was at times so rugged that standard mortar carts or jeeps could not be used, and the CWS had to devise a mule pack.[10]

[8] (1) CWTC Item 1060, Military Requirements and Military Characteristics for Jet Accelerator Adapter, for 4.2-Inch Chemical Mortar, 7 Jul 44. (2) CWTC Item 1180, Cancellation of Military Requirements for Jet Accelerator Adapter for 4.2-Inch Chemical Mortar Shell, 26 Oct 44.

[9] (1) Gilbert C. Bowen, Tests of Various Methods of Obtaining Rotation of the 4.2-Inch Chemical Mortar Shell. OSRD 5694, Oct 45. (2) Gilbert C. Bowen, C. F. Curtiss, R. B. Kershner, and Maj A. R. T. Denues, Extension of Range of the 4.2-Inch Chemical Mortar, M2. OSRD 5789, Jun 46.

[10] (1) CWTC Item 531, Standardization of 4.2-Inch Chemical Mortar and Ammunition Cart, 4 Aug 42. (2) TB 3-320-5, Mule Pack M2, 13 May 44. (3) TM 3-320, Jun 45.

4.2-INCH CHEMICAL MORTAR *in action, Arundel Island, New Georgia, September 1943. HE ammunition for the mortar is stacked at the right.*

This constant use of mortars took its toll in worn and damaged parts, much harm being caused by attempts to get more service out of the mortar than it had been designed to deliver. The CWS Technical Division set out to produce an entirely new mortar that would be free from the limitations inherent in the basic design of the M2 model which had been intended originally to fire a range of 2,400 yards. By the end of the war an experimental model, E37, had been constructed and test fired at Edgewood. After the war the service continued development until 1949 when the War Department, feeling that the mortar was now a legitimate weapon of the infantry, transferred the responsibility for development to the Ordnance Department. The Ordnance Department made a few final modifications and standardized the mortar as model M30 in 1951.[11]

American troops who saw the chemical mortar in action in the Pacific and in Europe had a high opinion of the weapon. German and Japanese troops respected its fire power and accuracy. Generalleutnant

[11] (1) Theodore R. Paulson, Development Summary of the E37R4 4.2-Inch Chemical Mortar. CWS 314.7 4.2-Inch Mortar R&D File. (2) Theodore R. Paulson, Development of E37 Chemical Mortar. DPGMR 32, Jul 47. (3) OCM 33579, 15 Feb 51.

Ochsner of the chemical warfare branch of the German Army, stated that "from the technical point of view the American 4.2-inch chemical projector is very good; the construction is simple, it is a very handy weapon in battle and its firing efficiency is high." [12]

The German Army had two types of chemical mortars, the smaller with a caliber of 8 cm. (approximately 3.2 inches) and the larger of 10 cm. (3.9 inches). The 8-cm. mortar was smoothbore, like the old Stokes, and was similar to the 81-mm. mortar issued by the Ordnance Department to American infantry. The complete weapon weighed 125 pounds, and had a range of from 450 yards to 1,300 yards. German mortar shells were pear shaped with fins fastened to the tail to stabilize their flight. The 10-cm. mortar was more complicated than either the 8-cm. or the American 4.2-inch in that it was a breech-loading weapon with a hydropneumatic recoil mechanism. It was mounted on a two-wheel chassis and weighed approximately a ton, six times heavier than the 4.2-inch mortar. The heavy weight and the wheeled mount greatly restricted the mobility of the weapon, a distinct disadvantage in comparison to the easily transported 4.2-inch mortar. The maximum range was 6,800 yards.[13]

The principal Japanese ground weapon for the employment of chemical munitions was the 90-mm. (3.5-inch) mortar. This was a smoothbore weapon that fired a dart shaped, fin tailed shell. Its total weight was 350 pounds, slightly heavier than the 4.2-inch mortar, and its maximum range was about 4,200 yards.[14]

Mortars of Unusual Design

While the 4.2-inch mortar was the workhorse of CWS troops during World War II, members of the technical staff experimented with other models. Following a suggestion of the Chemical Warfare Board in 1943 that fewer mortars would be needed and targets could be changed more rapidly if the weapon could swing through a full circle, engineers began development of a special mortar with a traverse of 360°. They designed several models, one or more of which might ultimately have been satisfactory, but finally dropped the project when the AGF decided that a mortar

[12] Ochsner, History of German Chemical Warfare, pt. I, p. 33.

[13] (1) German Chemical Warfare, pp. 119–20. (2) German Chemical Warfare Materiel, pp. I-A-1, I-A-2.

[14] Enemy Capabilities for Chemical Warfare, pp. 92–96.

with such an extreme traverse was unnecessary. Along with the 360° mortar the men experimented with a mortar of 90° traverse, but the weapon was not particularly successful, and the project ended with the war.[15]

To simplify the training of mortar squads the Chemical Warfare Board devised an ingenious subcaliber mortar consisting of a steel pipe that fitted inside the standard mortar barrel. The shell was fashioned of steel and wood and could be used over and over. The weapon was fired in the regular manner, and ranged from 115 to 400 yards. A small glass bottle of smoke solution could be fitted to the nose to give the appearance of a miniature explosion when the shell landed. Not the least of the merits of this subcaliber mortar was that it dropped the cost of firing a training round of ammunition from several dollars to thirteen cents.[16]

In 1943, at the suggestion of Col. William A. Borden, Ordnance Department, who had conducted a survey of munitions in the Pacific Islands, the CWS began to develop a mortar which could fire horizontally into low Japanese bunkers of coconut logs and earth. The standard mortar barrel could not be dropped below an angle of 45° with the horizon, and a way had to be found of holding the barrel level with the ground and at the same time neutralizing the tremendous recoil of a quarter of a million pounds. Engineers at the CWS Laboratories at Columbia University devised a method of leveling the mortar by a new baseplate that could be bolted or chained to the trunk of a tree. While this solved the recoil problem—as long as mortar companies fought in wooded areas—it did not end the development work. When a mortar fired on a flat trajectory, for which it had never been designed, unusual strains were set up in the weapon. These had to be overcome by redesigning certain components. Even the shell was modified and its weight increased. Tests proved that the new model would be satisfactory in the field, but the weapon was not carried beyond the experimental stage because a recoilless mortar, which the CWS had started to develop at almost the same time, offered a better

[15] (1) Ltr, CWB to CWTC, 10 Jan 43, sub: Modified "Armstrong" Baseplate and Mount for 4.2-Inch Chemical Mortar. CWB 472.42/69. (2) CWTC Item 726, Military Requirement and Military Characteristics for 4.2-Inch Chemical Mortar with 360° Traverse, 11 Jun 43. (3) CWTC Item 1226, Cancellation of Military Requirements for 4.2-Inch Chemical Mortar with 360° Traverse. (4) CWTC Item 997, Military Characteristics for 4.2-Inch Chemical Mortar, 5 May 44.

[16] (1) Chemical Warfare Board Project No. 279, Sub-Caliber Trainer for 4.2-Inch Chemical Mortar, 27 Sep 43. (2) CWTC Item 952, Standardization of Mortar, Sub-Caliber, 3-Inch, M3; Charge, Smoke, 3-Inch Sub-Caliber Shell, M1; and Charge, Propelling, 3-Inch Sub-Caliber Shell, M8, 17 Mar 44. (3) TB 3-320-2, Training Accessories for the 4.2-Inch Chemical Mortar, 29 Feb 44.

possibility of solving the multitude of problems that accompanied the change from angular to horizontal firing.[17]

A recoilless gun was open at both ends instead of one end as in the conventional gun. When the propellant charge exploded, the shell sped forward through the barrel while the gas blew backward through the breech. The gun, shell, and propellant were designed to make the forward action equal to the backward reaction, eliminating recoil.

Recoilless weapons had been investigated by the American Army in World War I. In World War II the idea was revived by the Germans, the British, and then by the Ordnance Department. When the CWS began development of a horizontal mortar, it realized that the principle involved in a recoilless gun might be applied, and in October 1943 General Kabrich asked Dr. C. N. Hickman, Chief of Section H, Division 3, NDRC, to undertake the development of a mortar having no recoil.[18] That same month the first recoilless attachment to fit on the breech of the standard mortar barrel was designed, and in November firing trials were started. Step by step the ignition system, firing mechanism, reaction chamber, and shell were perfected. The shell was fired in an unusual manner. A small rocket, called a rocket driver by the designers, was attached to the fuze. When the mortar was fired the rocket driver hurled the shell back into the barrel where it struck the firing pin. The firing pin then detonated the propellant charge and started the shell forward. The rocket driver fell off while the shell was in the air, exposing the fuze.

By August 1944 the model was ready for a full-scale demonstration at Edgewood. Service officers were so impressed that they ordered the gun completed under top priority. The final, standard model consisted of a two-piece barrel mounted on a caliber .30 machine gun tripod. Targets 3,800 yards away could be hit, but accuracy was best below 1,000 yards. The 28-pound HE shell easily demolished replica Japanese bunkers of earth and logs.[19]

[17] (1) Col Borden's suggestion is cited in Ltr, Brig Gen W. C. Kabrich, C, Tech Div, OC CWS to Dr. C. N. Hickman, C, Sec H, Div 3, NDRC, 8 Nov 43. SPCVD 472.4 GWU. Reprinted as App. A, OSRD 5791. (2) Baum, Columbia University Chemical Warfare Laboratories. (3) Lt Milton Stern, Lt L. L. Smith, and Charles T. Mitchell, Experiments with Horizontal Firing of 4.2-Inch Mortar for Jungle Use. TDMR 1029, 10 May 45.

[18] (1) Ltr, Kabrich to Hickman, 8 Nov 43. (2) Green, Thomson, and Roots, *Planning Munitions for War*, pp. 328–31. (3) Interv, Hist Off with Wendell H. Kayser, 4 Feb 57.

[19] (1) R. B. Kershner, Maj A. R. T. Denues, J. M. Woods, S. Golden, J. Levin, and Capt F. Culp, Recoilless 4.2-Inch Chemical Mortars. OSRD 5791, Apr 46. (2) CWTC Item 1384, Standardization of Mortar, Chemical, 4.2-Inch, Recoilless, M4, 2 Aug 45. (3) TB CW 24, 4.2-Inch Recoilless Chemical Mortar, E34R1, 21 Dec 44.

The CWS contracted for the manufacture of 1,000 recoilless mortars, 100 of the weapons being completed before the end of the war. Recoilless mortars reached the Tenth Army in the Pacific theater in time for the Okinawa campaign, but otherwise they were produced too late for battle use.[20]

Mortar Shells

The 4.2-inch mortar shell with fuze weighed 18 pounds, and held approximately 7 pounds of chemical agent. At the beginning of the war the authorized toxic fillings were mustard, lewisite, phosgene, CNB (a solution of chloroacetophenone in benzene and carbon tetrachloride), and CNS (a solution of chloroacetophenone and chloropicrin in chloroform). Later cyanogen chloride was added. Some measure of the service's opinion of the relative value of different toxic agents for gas shoots may be gauged from the number of shells filled with various agents from 1940 to 1946: 540,746 contained mustard; 49,402, phosgene; 41,353, CNS; 12,957, CNB; and 175, lewisite.[21]

The German Army came close to the American Army in its stockpile of mustard filled shells, some 400,000 10-cm. mustard-arsenöl shells coming to light after the war. No other chemical mortar shells were found. They either may have decided that other fillings were not satisfactory or else they were not able to put other shells into production.[22]

The Japanese had a variety of toxic filled munitions for use with their 90-mm. mortar. One type of shell held a half pound of diphenylcyanoarsine, a vomiting agent, and a pound of TNT. The TNT scattered the agent in aerosol form besides acting as a high explosive. Another shell held two pounds of blistering agent, generally a fifty-fifty mixture of lewisite and mustard. Shells containing hydrogen cyanide were also reported among Japanese supplies.[23]

American mortar shells held more agent than either Japanese or German shells. They contained from 6.25 to 7.56 pounds of chemical, depending

[20] (1) CWTC Item 1785, Obsoletion of the Mortar, Chemical, 4.2-Inch Recoilless, M4, and the Shell, 4.2-Inch Recoilless Chemical Mortar, M6, with Cancellation of Related Military Requirements and Development Type Items, 25 Sep 47. (2) Roy E. Appleman, James M. Burns, Russell A. Gugeler, and John Stevens, *Okinawa: The Last Battle,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1948), p. 38.

[21] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21. The phosgene shells include 2,000 containing 10 percent nitrogen dioxide, a red gas for spotting purposes.

[22] German Chemical Warfare, pp. 128–31.

[23] (1) CW Intell Bull No. 49, pt. I. (2) Enemy Capabilities for Chemical Warfare, pp. 92–96.

upon the physical characteristics of the chemicals. Thus the total weight of filled shells varied from 24 to 26 pounds. In terms of percentage, the agent comprised from 26 percent to 30 percent of the shell. In contrast, German 10-cm. mustard-arsenöl shells weighing 15 pounds held 3 pounds, or 20 percent, of agent; and Japanese 90-mm. shells weighing 12 pounds held 2 pounds (17 percent) of vesicant agent, or 0.5 pound (4 percent) of vomiting agent. Shell for shell, the 4.2-inch mortar could have laid down a heavier concentration of gas on an area than the enemy mortars.[24]

The possibility that chemicals would be used during the war was the reason for the mortar's presence among CWS troops; yet chemical shells, with the exception of smoke shells, were never fired. It was the HE shell which gained for the mortar the high regard of infantrymen. When the CWS received permission to use HE, munitions experts modified the standard shell slightly, removed the vanes and burster tube, and then loaded the missile with TNT. An HE shell, with fuze, weighed twenty-two pounds, and the explosive charge weighed eight. This quantity of TNT, approximately one-third of the weight of the filled shell, represented a high loading efficiency, and the blast and fragmentation effect of the shell upon impact was tremendous. In September 1942, the CWS standardized this shell as model M3.[25]

During the course of development work the CWS Technical Command produced several experimental mortar shells, one of which, a high explosive fragmentation shell with good flight characteristics and ballistic properties, was superior to the M3 shell in demolishing Japanese-type pillboxes. The shell wall was twice as thick as that of the standard HE shell, while the filling of TNT was a bit less, 6.6 pounds. In November 1943 a CWS representative returning from the Southwest Pacific Area reported that such a shell was needed immediately. The CWS designated the new shell as model M4 and ordered a large supply.[26]

In the spring of 1944 the Field Artillery Board compared the new M4 with the older M3 in a series of tests against targets in shelter trenches and open fields. In percussion, ricochet and low-angle time fire, shell fragments from the M3 scored more hits than fragments from the M4. In

[24] (1) TM 3-320. (2) German Chemical Warfare Materiel, I-C-1. (3) CW Intell Bull No. 49, pt. I.

[25] (1) CWTC Item 530, Standardization of High Explosive 4.2-Inch Chemical Mortar Shell, 4 Aug 42. (2) CWTC Item 571, same title, 29 Sep 42.

[26] (1) Theodore R. Paulson, Milton Stern, and L. L. Smith, Tests of Experimental Shell for 4.2-Inch C. M. TDMR 1075, 23 Aug 45. (2) CWTC Item 869, Standardization of Shell, HE, 32-lb, 4.2-Inch Chemical Mortar, M4, 3 Dec 43.

high-angle time fire both projectiles produced about the same number of hits. As a result of these tests the CWS halted the production of the new shells, and thereafter used them only when there was a shortage of the M3 shell.[27] About 67,000 new M4 shells were manufactured, in comparison with the more than 6,400,000 of the M3 type.[28]

Smoke shells made up a large fraction of the service's output of mortar ammunition. Authorized smoke fillings included white phosphorus (WP), a solution of sulphur trioxide in chlorosulfonic acid (FS), and titanium tetrachloride. "The American white phosphorus ammunition was outstandingly good," wrote Generalleutnant Ochsner, after the war.[29] These shells threw up a large volume of dense white smoke that was useful as a marker or as a smoke screen. Burning chunks of phosphorus flying through the air frightened enemy soldiers. Phosphorus could ignite dry underbrush, hay, paper, and other combustibles, and thereby serve as an incendiary. And finally the agent could cause casualties among enemy troops by inflicting burns. Mortar squads fired quantities of WP second in volume only to HE. Over three million WP shells came from filling plants in the United States, more than all other mortar shells—excluding HE—combined. In comparison, the service procured only one-third of a million FS smoke shells, and none containing titanium tetrachloride.[30]

The German Army would have been happy to have had the same plentiful supply of WP as the American Army, but Germany lacked the raw materials for producing phosphorus, and its army had to depend on inferior Berger mixture or on sulphur trioxide.[31]

In addition to chemical, HE, and smoke shells, the CWS developed other types of mortar ammunition for special purposes. In 1943, the Chemical Warfare Board suggested that an incendiary shell might be useful in driving enemy soldiers from wooded positions or combustible buildings. After a preliminary study the question arose as to whether such a shell would be worth the time spent on it. The CWS canvassed chemical officers in the various theaters and found only one who thought that the shell might be useful. As a result of this survey the project was dropped. But in the spring of 1944 the service revived the idea when the European theater showed interest in an incendiary shell. Munitions engineers at CWS

[27] (1) CWTC Item 1011, Reclassification of Shell, HE, 32-lb, 4.2-Inch Chemical Mortar, M4, 5 May 44. (2) CWTC Item 1070, same title, 7 Jul 44.

[28] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[29] Ochsner, History of German Chemical Warfare in World War II, p. 33.

[30] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[31] Oschner, History of German Chemical Warfare in World War II, p. 33.

designed a base ejection shell holding four hollow magnesium incendiary cylinders filled with thermite mixture. The shell acted like a small mortar. As it struck the target an explosive charge in the nose blew the burning cylinders backward through the tail, and the magnesium in turn, set fires in the target area. This shell was just being perfected as the war ended.[32]

In March 1944 the Commanding General, Central Pacific Area, requested an illuminating shell. The CWS had had no experience with this type of projectile, but both the Ordnance Department and the Navy had shells which, upon bursting, released a flare fastened to a parachute. Service engineers modified the Navy flare to fit the mortar shell, following the standard naval practice in mixing and loading flare compositions. They produced experimental shells that functioned perfectly, but these came too late in the war for standardization.[33]

In May 1944 the Commanding General, South Pacific Area, asked for colored smoke mortar shells. Chemists developed mixtures containing dyes that produced red, yellow, green, and violet smokes. With a fuze set for an air burst, shells containing these smokes erupted a colored cloud visible for some miles and lasting for several minutes in calm weather. Colored smoke shells were recommended for standardization shortly before the end of the war.[34]

Starting with one basic type of shell in 1942, the CWS evolved a variety of shells for the 4.2-inch mortar. Only three of these, HE, white phosphorus, and FS smoke, were employed in battle, but their effectiveness led Generalleutnant Oschner to say, in speaking of the American mortar, that "the various types of ammunition used with it are excellent." [35]

Mortar Gunboats

The CWS in 1942 experimented with mortars mounted on landing craft, including the LCI's and the LCT's. It took the view that mortars

[32] (1) CWTC Item 1326, Military Requirement and Military Characteristics for Incendiary, 4.2-Inch Chemical Mortar Shell, 24 May 45. (2) Alfred E. Gaul and Leo Finkelstein, Incendiaries, vol. 18, 31 Jan 52, in monograph series, History of Research and Development of the CWS (1 July 1940–31 December 1945), pp. 665–75.

[33] (1) Capt T. A. Ruble, 4.2-Inch Chemical Mortar Shell, Illuminating, E 71. TDMR 1030, 16 May 45. (2) CWTC Item 1059, Military Requirement and Military Characteristics for 4.2-Inch Chemical Mortar Illuminating Shell, 7 Jul 44.

[34] (1) CWTC Item 1052, Military Requirement and Military Characteristics for 4.2-Inch Chemical Mortar Colored Smoke Shell, 7 Jul 44. (2) Leo Finkelstein, Colored Smokes, vol. 12, 1 May 48, monograph in series, History of Research and Development of the CWS (1 July 1940–31 December 1945), pp. 91–94.

[35] Oschner, History of German Chemical Warfare in World War II, p. 33.

could support an amphibious assault in the crucial period of an invasion, after the naval and air bombardment let up so that troops might land. Mortars could not be placed directly on the bottom of landing craft, since there was no way to keep the recoil from kicking mortars backward when the piece was fired. In addition, the terrific pounding might damage the bottom of the vessel.

Technicians rigged an oblong wooden frame, filled with a mixture of sand and sawdust, on the floor of the craft. A thick slab of wood, grooved to take the bottom of the baseplate, sat on top of the sand-sawdust filling. This served as an artificial land emplacement for the mortar. The Amphibious Training Command, Carrabelle, Fla., to which the CWS sent the firing platform, saw the utility of the device and asked the service to design a standard model.[36]

In July 1943 a chemical mortar battalion with weapons mounted in landing craft took part in the seaborne assault on Sicily. The battalion was ready to fire from its offshore positions, but the need did not arise. Mortar gunboats first saw action in the Pacific, where amphibious warfare was more common. On 15 September 1944, 4.2-inch mortars mounted on landing craft, infantry (LCI), supported the 1st Marine Division in its assault on Peleliu.[37] Two days later at Angaur Island, mortar gunboats fired on the beach area as troops of the 81st Division swarmed ashore. Offshore LCI's afterwards lobbed mortar shells into Angaur to support infantry attacks.[38]

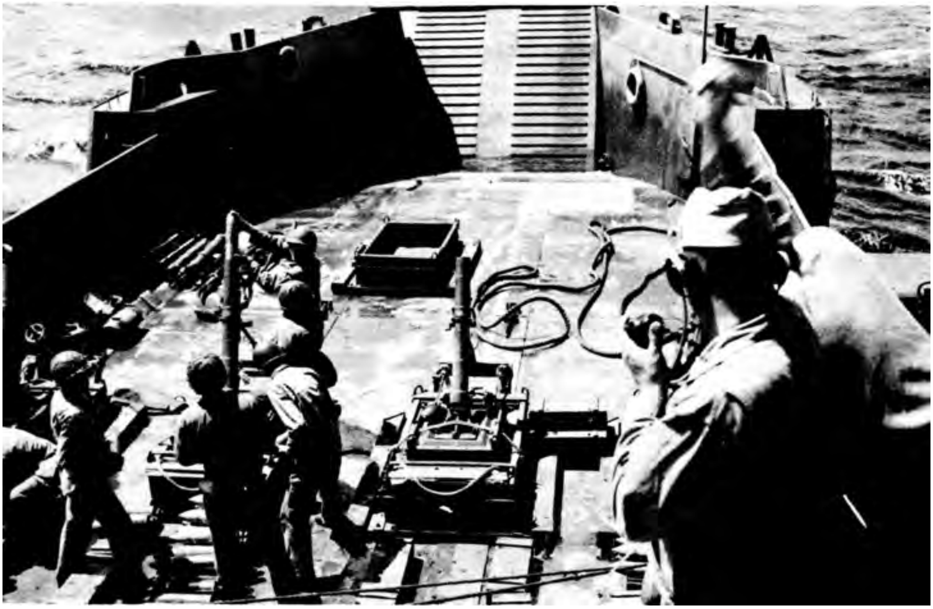
On D-day at Iwo Jima, the heavy gunfire-support ships of the invading force were augmented by 18 LCI's armed with 4.2-inch mortars. During the night of 20-21 February LCI's with mortars delivered counterbattery and harassing fires in supporting the V Amphibious Corps. Since LCI's had no radar and only inadequate navigating gear, they followed the ingenious plan of steaming in an elliptical track around a reference ship that kept station by radar, firing during the time they were on the path of the ellipse and headed toward the island.[39] On Easter Sunday, April 1945,

[36] (1) Robert W. Elton and Lt Donald W. Gerlitz, 4.2-Inch Emplacement for Landing Craft, Vehicular. TDMR 640, 7 May 43. (2) TB 3-320-1, 4.2-Inch Chemical Mortar Mount LC, E2R2, 27 Jan 44.

[37] See Paul W. Pritchard, Brooks E. Kleber, and Dale Birdsell, The Chemical Warfare Service: Chemicals in Combat, a volume in preparation for the series, UNITED STATES ARMY IN WORLD WAR II.

[38] Robert Ross Smith, *The Approach to the Philippines*, UNITED STATES ARMY IN WORLD WAR II (Washington, 1953), pp. 500, 519.

[39] Lt Col Whitman S. Bartley, *Iwo Jima: Amphibious Epic*, Marine Corps Monograph (Washington, 1954), pp. 49, 83-84.



MORTAR GUNBOAT. *Crew preparing to fire one of the 4.2-inch chemical mortars mounted on the deck of an LCT.*

forty-two mortar gunboats were among craft that led the way to the landing beach at Okinawa. One hundred and twenty-six mortars laid down 28,000 shells over a strip five and one-half miles long and one thousand feet deep in less than an hour.[40] All in all, LCI(M)'s (the M for mortar), as the mortar mounted craft came to be designated, participated in a dozen landings in the Pacific during the latter part of 1944 and the war months of 1945.[41]

[40] Appleman, *et al.*, *Okinawa*, p. 70. (2) *The Chemical Warfare Service in World War II*, p. 150.
[41] (1) Maj. R. H. Skinner, "Famed 4.2 Rides Waves," *Armed Forces Chemical Journal* I (October 46), 44–45. (2) "The 4.2 Goes to Sea," *Chemical Warfare Bulletin* 31 (Jan–Feb 45), (3) *Chemical Warfare Service in World War II*, pp. 148–50.

CHAPTER VII

Flame Throwers

Portable Flame Throwers

On 8 December 1942 near Buna Village, Papua, Corp. Wilbur G. Tirrell crawled through the underbrush to a spot some thirty feet from a Japanese emplacement. He stepped into the open and fired his flame thrower. The flaming oil dribbled fifteen feet or so, setting the grass on fire. Again and again Corporal Tirrell tried to reach the bunker, but the flame would not carry. Finally a Japanese bullet glanced off his helmet, knocking him unconscious. This was the first time an American flame thrower had ever been used in combat. It failed so miserably that Col. William A. Copthorne, Chief Chemical Officer, USAFFE, believed that infantrymen would never want to use flame throwers again. Yet the weapon had distinct advantages, and before the war was over the armed forces had first-rate models.[1]

Flame throwers were introduced by the German Army in 1915, and then adopted by other European armies. Americans, using European weapons as models, began to develop flame throwers in 1917, but the armistice was reached before they were completed. The American Expeditionary Forces was not enthusiastic about the flame thrower—General Fries called it "one of the greatest failures among the many promising devices tried out on a large scale in the war"—and after the conflict the Chemical Warfare Service dropped the weapon completely.[2] So it was that in July 1940

[1] (1) Samuel Milner, *Victory in Papua,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1957), p. 250. (2) Lt Col Leonard L. McKinney, Portable Flame Thrower Operations in World War II, Chemical Corps Historical Studies No. 4, 1 Dec 49, p. 58.

[2] Fries and West, *Chemical Warfare,* pp. 352, 401.

when the Corps of Engineers asked the CWS for a portable flame thrower the service had to go back to the beginning and start all over again.[3]

The Kincaid Co. of New York manufactured a few of the first experimental models, designated as E1, in the autumn of 1940. This and all subsequent models consisted of four main components: a storage system for fuel, a storage system for compressed gas, a flame gun, and an igniter. Each was an indispensable component and each required considerable development. The first fuel tank was a vertical cylinder having two compartments, the upper holding nitrogen under pressure and the lower containing five gallons of fuel—at that time diesel oil, fuel oil, or a blend of gasoline and oil. The filled weapon weighed seventy pounds. The fuel oil flowed through a flexible tube into the flame gun. The gun was a metal barrel to which was fastened an igniter consisting of a battery and a cylinder filled with compressed hydrogen. The gun had two triggers, one to release the fuel and the other for ignition as it issued from the nozzle. When the weapon was fired, compressed nitrogen blew the oil through the hose and gun at the rate of one-half gallon per second. At the nozzle an electric spark from the battery lit a small jet of hydrogen, which in turn set aflame the oil. The stream of burning oil had a range of fourteen to twenty-one yards.[4]

The Engineer Board tested the weapon and decided it was not ready for military operations. The combination fuel-compressed gas reservoir was impractical, a bend in the gun barrel made the flame thrower difficult to fire from a prone position, the gas pressure dropped steadily while the weapon was being fired, decreasing the range. The entire apparatus was cumbersome, heavy, and undependable. The CWS redesigned the flame thrower, and contracted with the Kincaid Co. for a better model, E1R1, which reached Edgewood in March 1941. Now the fuel and compressed nitrogen were stored in separate reservoirs, a feature retained in all future

[3] (1) The flame throwers developed in 1917–18 are described in: (a) Arthur B. Ray, Incendiaries, Chemical Warfare Monograph, vol. 43, May 1919, pt. II, pp. 186–201; (b) Fries and West, *Chemical Warfare,* pp. 347–52. (2) Ltr, C Engr to TAG, 24 Jul 40, sub: Flame Thrower for Individual Use, with inds. This letter is reprinted in CWTC Item 221, 10 Sep 40.

[4] (1) The range of the flame thrower cannot be stated exactly because it varied with the composition of the fuel, the pressure of the gas, and with the individual weapon. The figures given in this chapter are average, not the maximum obtained under ideal conditions. (2) The E1 and all other flame throwers, as well as the basic scientific factors involved, are discussed in Leo Finkelstein, Flame Throwers, vol. 15, 1 May 49, in monograph series History of Research and Development of the Chemical Warfare Service in World War II. (3) A résumé of the work done by the CWS may be found in Report of Activities of the Technical Division During World War II (1 Jan 46), pp. 136–49.

OPERATOR FIRING A PORTABLE FLAME THROWER E1R1 *at a concrete fortification during a test of the weapon.*

models. The gun, the ignition system, and the valves were all improved. The weapon weighed 28 pounds empty and 57 pounds loaded.[5]

The E1R1 was far from perfect—parts were easily broken, valves were hard to reach unless the operator was a contortionist, and the weapon made an uncomfortably heavy load on the operator's back—but the weapon held a range of 15 to 20 yards for 15 to 20 seconds and on the whole seemed suitable for use in special situations. Since the few that had been produced for the purpose of testing were the only practical American flame throwers in existence, the Army issued them to troops in training camps. Some troops actually carried these crude weapons overseas to the Pacific Islands and employed them in battle. Corporal Tirrell's assault on a Japanese bunker was made with one of these, an E1R1.

The CWS in the meantime had been rushing an improved version of the E1R1 through final development. Suggestions from test boards had led to a slightly heavier, more rugged, longer range model standardized

[5] The Report of the Engineer Board is quoted in Capt. L. W. Russem, Theodore Loew, and C. T. Mitchell, Development of the Portable Flame Thrower M1, M1A1, and M2-2. TDMR 1069, 19 Jun 45, p. 6. (2) Service Tests of Portable Flame Thrower EB 109, Report of the Engineer Board, Report No. 621, 16 May 41. (3) Report on Service Tests of Portable Flame Thrower E1R1, Report of the Infantry Board No. 1225, 20 Jun 41.

as M1. In March 1942 the weapons began coming off production lines, some reaching the South Pacific Area by the end of the year.

The new flame thrower was employed for the first time on 15 January 1943 by marines and infantrymen on Guadalcanal. An infantry attack against a stubborn enemy pocket holding up the advance of the 2d Battalion, 35th Infantry, did not succeed. But Marine engineers burned out three Japanese bunkers in a ravine, and thus helped rout enemy troops holding up a Marine advance.[6]

At that time the flame thrower was unfamiliar to the Army. Since most troops had never seen one before, they did not know what it could do. After its success on Guadalcanal the word spread around, and in later engagements in the Pacific, from New Guinea to the Ryukyus, foot soldiers always kept the flame thrower in mind when they had to overcome a stoutly defended Japanese position. This is not to say that the M1 was a perfect, reliable weapon. One specimen, just received from the States, might function properly and spurt a jet of flame the customary fifteen yards, but its twin might eject a harmless stream of nonburning oil a distance of five yards. Batteries in the ignition circuit deteriorated rapidly in the hot, humid, climate; inadequate waterproofing allowed moisture to corrode parts and to short-circuit the electrical system; and minute rust holes in tanks allowed compressed gas to escape and the pressure to drop. Chemical maintenance companies had their hands full inspecting, testing, repairing, and servicing flame throwers to keep them in proper working order for the troops.

The weapon that replaced the M1 came about as a result of the invention of napalm, developed originally to thicken gasoline fillings in incendiary bombs.[7] The CWS tested thickened gasoline in flame throwers and found that the range was greater than with ordinary gasoline. Furthermore, ordinary gasoline broke into a spray after it left the nozzle of the flame gun and burned itself out in a billow of fire while thickened fuel flew through the air in a compact stream that would ricochet into portholes and stick to flat surfaces.

Unfortunately, the M1 flame thrower could not get the greatest range out of the new thickened gasoline, for it was like running a 1910 model automobile on modern premium fuel. In August 1942 Col. William C.

[6] (1) McKinney, Portable Flame Thrower Operations, pp. 39–40. (2) John Miller, jr., *Guadalcanal: The First Offensive*, UNITED STATES ARMY IN WORLD WAR II (Washington, 1949), pp. 279, 295. (3) Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[7] See p. 169.

Kabrich, chief of the CWS Technical Division, appointed a joint CWS-NDRC committee to modify the weapon. To keep from upsetting the procurement program, Colonel Kabrich asked the committee to make the changes in the M1 as few and as simple as possible. The committee modified the fuel system, pressure regulator, valves, and flame gun to permit the higher operating pressure necessary to obtain the maximum range with napalm, and at the same time improved the waterproofing.[8] The CWS-MIT Laboratory tested napalm-gasoline mixtures to find the one giving the greatest range.[9]

The new flame thrower, M1A1, could expel thick fuel two or three times as far as the old model. In aiming at the port of a pillbox fifty yards away it could place half of the thickened fuel inside the structure. The old model could not reach a pillbox fifty yards away, and could place only about 10 percent of its charge in a pillbox twenty yards away. The improved electrical system was still not entirely reliable, but on the whole the new weapon was so superior to the M1 that the CWS decided to produce and issue it immediately.

Initial shipments of the fourteen thousand M1A1 flame throwers manufactured during World War II arrived in the Mediterranean theater in June 1943, the South Pacific Area in July, and the Southwest Pacific Area in August.[10] This model gave good service throughout the war, but occasionally the electrical ignition system failed. When this happened the troops dropped the weapon or else lit it by some other means. In the landing on Leyte, 20 October 1944, a flame thrower failed to ignite when the operator fired it at a pillbox. Nearby Pfc. Frank B. Robinson, 19th Infantry, threw a handful of burning paper in front of the pillbox. The operator ignited the fuel by firing it through the flames from the paper.[11] In an action at Azeville, France, 9 June 1944, Pvt. Ralph G. Riley ran up to a German blockhouse with his flame thrower, only to find that the ignition system would not work. He held a match near the nozzle and ignited the stream of fuel. Ammunition exploded inside of the fortifica-

[8] *Fire Warfare: Incendiaries and Flame Throwers* (Washington, 1946), p. 96. This is Volume 3 Summary Technical Report of Division 11, NDRC. (2) A résumé of the work done by the NDRC on flame throwers may be found in *Fire Warfare;* Noyes, *Chemistry,* pp. 420–30; James Phinney Baxter, 3d, *Scientists Against Time* (Boston: Little, Brown, and Company, 1946), 294–97.

[9] Hemleben, CWS-MIT Laboratory, pp. 54–68.

[10] McKinney, Portable Flame Thrower Operations, pp. 14, 182.

[11] M. Hamlin Cannon, *Leyte: The Return to the Philippines,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1954), p. 69.

ATTACKING A JAPANESE BUNKER *with an M1A1 portable flame thrower, Bougainville, March 1944.*

tion, the garrison of 169 men surrendered, and Private Riley received the Silver Star.[12]

The final portable flame thrower appeared in 1944. In developing this weapon the Chemical Warfare Service and the National Defense Research Committee set out on different roads to find the best method of ignition, and to design a more rugged, comfortable, dependable weapon. The NDRC contractor, Standard Oil Development Co., produced a model known as the E2. This featured a long-life battery, waterproof electrical system, lightweight aluminum fuel tank, and gasoline ignition system. The CWS turned out a weapon, E3, with a streamlined gun, improved valves, a comfortable pack similar to the standard Quartermaster packboard used for carrying mortar shells and other ammunition, and a cartridge type of ignition. The latter was similar to a revolver. It held six cartridges, each filled with a pyrotechnic mixture. When the operator pressed the trigger a shower of sparks erupted from the cartridge and ig-

[12] Gordon A. Harrison, *Cross-Channel Attack,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1951), p. 390.

FIRING AN M2-2 PORTABLE FLAME THROWER *into a wall opening, Manila, Luzon, February 1945.*

nited the fuel. Six cartridges allowed the operator to fire up to six bursts.[13]

In comparative tests the CWS and NDRC models showed approximately the same range, sixty yards with thickened fuel and one-third of this with ordinary fuel. The former model was slightly heavier and held less fuel than the latter. The Army preferred the rugged CWS model with pyrotechnic ignition to the light NDRC model with electrical ignition, and adopted it as the standard model, M2-2 in March 1944.[14]

American troops first employed the M2-2 in the Guam operation in July 1944. Manufacturers turned out more of this model than all earlier models combined—almost 25,000 as compared with 14,000—but production difficulties slowed down the issue of flame throwers to theaters of operation. March 1945 arrived before divisions in Italy received the weapon,

[13] Development of Portable Flame Thrower, E2. OSRD No. 3574, 4 May 44.

[14] (1) In the new method of multiple designation used here, the first "2" referred to the gas and fuel reservoirs, the second "2" to the flame gun. (2) CWTC Item 935, Standardization of Flame Thrower, Portable, M2-2, Kit, Service, for Portable Flame Thrower, M2-2, and Cylinder, Ignition, Portable Flame Thrower, 17 Mar 44.

and some troops in the Pacific fought their last engagements of the war using the old M1A1.[15]

Although the M2-2 was better than its predecessor, it was not entirely satisfactory. It was too heavy, it did not hold enough fuel, and the fuel tanks were uncomfortable on the backs of the operators when the weapon had to be carried a considerable distance. It was, however, the most reliable flame thrower designed by any army up to that time. The CWS technicians continued to develop a light, large capacity weapon, but they did not reach their goal during the war.

The German Army, as the American, had portable-type flame throwers. The model in general use was *Flammenwerfer 41*. The fuel pack consisted of two steel cylinders, one containing approximately two gallons of fuel oil, and the other holding compressed nitrogen. A metal braided hose ran from the fuel pack to the flame gun. The original ignition system was similar in operation to the early CWS models; that is, an electrical spark from a small battery ignited a tiny jet of hydrogen. The Germans, too, had difficulty with this system and switched to a pyrotechnic cartridge. The filled flame thrower weighed approximately forty pounds, and expelled a jet of fuel from twenty-five to thirty-five yards.[16]

Japanese troops on occasion used flame throwers. Americans first faced them on Bataan in early February 1942, and shortly thereafter American soldiers captured two. The CWS laboratory staff at Fort Mills tested one flame thrower, and sent the ignition system to Edgewood where it was examined for usable features.[17]

Fuel packs on Japanese flame throwers were similar to the American type. Two cylindrical tanks held a mixture of oil and gasoline, while a small tank contained compressed nitrogen. A rubber hose connected the fuel pack and the flame gun. The ignition mechanism was a revolving cylinder holding ten pyrotechnic cartridges. Japanese weapons were lighter and held slightly less fuel than the American models. The range was somewhat more than the E1R1, M1, and M1A1 models, but less than Model M2-2.

The Japanese flame throwers were well made. Colonel Hamilton, chem-

[15] (1) McKinney, Portable Flame Thrower Operations, pp. 190, 227. (2) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 24.

[16] (1) German Chemical Warfare, World War II, p. 141. (2) WD Intel Bull, Apr 44, pp. 22-28.

[17] Hamilton, Activities Chemical Warfare Service, Philippine Islands, World War II, 22 Nov 46, sec. B, pp. 21-30.

AMERICAN AND GERMAN PORTABLE FLAME THROWERS. *U.S. flame thrower M2-2, left; German 1942 model, right.*

ical officer in the Philippines, stated his opinion in early 1942 that the "United States principle and basis of flame thrower research and development is somewhat inferior and less practical than the Japanese principle." [18] The Japanese weapon was of course not foolproof. The ignition cartridges were susceptible to moisture, and at times would not throw off a shower of sparks. In many instances in the Pacific Islands American tanks and troops who were fired on escaped with only a harmless shower of oil.

The One-Shot Flame Throwers

One disadvantage of the portable flame thrower was its weight, about 70 pounds including fuel. In December 1942 the chemical officer, Fifth Army, recommended the development of a single-shot flame thrower light enough for a man to carry long distances, and inexpensive enough to be discarded after firing. In addition to its light weight and low cost

[18] Ltr, Col Stuart A. Hamilton, USFIP, to C CWS, sub: Status of Improvised Flame Thrower, Philippine Islands, 16 Apr 42. Copy in Activities Chemical Warfare Service, Philippine Islands, World War II, sec. A, p. 64.

the weapon could be shipped from the United States ready for use, thus saving the time of maintenance crews.[19]

The first crude model was cylindrical in shape, thirty-four inches long, and five inches in diameter. Inside at the butt end was a pressure bottle taken from a carbon dioxide fire extinguisher to provide gas for expelling the fuel. Seated against the pressure bottle was a piston. Between the piston and the nozzle were two gallons of fuel. The weapon was simple to operate. The soldier held it tightly against his body as he might the nozzle of a fire hose, and then pulled the firing pin. This released a steel spike which pierced the gas bottle. Escaping carbon dioxide pushed the piston forward, squirting the fuel out through the nozzle. A railroad fusee ignited the charge. The effective range of the flame thrower was about thirty yards.[20]

The Army was at first not particularly interested in the one-shot flame thrower and CWS engineers worked on the device only when they could spare time from other jobs. After the portable model proved valuable in jungle fighting, the service hastened development of the one-shot. The NDRC assisted by letting a contract with the Firestone Tire and Rubber Co. Firestone in the summer of 1944 designed a model containing compressed gas stored in a long, steel tube coiled around the outside. The maximum effective range was forty yards, the weapon emptying in four seconds.[21]

A new method of propelling fuel had meanwhile been suggested—gas from a combustible powder. Powder would eliminate carbon dioxide coils, it would simplify charging the weapon, and it would ease the problem of supply. The NDRC produced a model in which powder gave off gas at a pressure of 1,000 pounds per square inch. This pressure was great enough to shoot unthickened gasoline twenty-five yards. When the war ended the one-shot had reached the stage where the CWS was ready to produce some for battle testing.[22]

The American Army was not alone in seeking a light flame thrower. Toward the end of the war the German Army produced *Einstossflammenwerfer 46,* a single-shot close combat weapon for assault troops and paratroopers. The barrel was two feet long and three inches in diameter. It was lighter than the CWS weapon—it weighed only six pounds filled—

[19] McKinney, Portable Flame Thrower Operations, p. 190.

[20] T. Loew, Development of One-Shot Flame Thrower, E15. TCIR 215, 15 Nov 44.

[21] Flame Thrower, Portable, One-Shot, E15. TB CW 28, 28 Mar 45.

[22] (1) *Fire Warfare,* pp. 101–02. (2) The Status of ABL Projects as of VJ-day. OSRD 5932, 3 Sep 45.

but in reducing the weight the designers reduced the fuel capacity to one and one-half quarts. The pressure to expel the fuel was provided by gas from an exploding cartridge. The range averaged thirty yards. Germany seems to have been alone among the enemy countries in producing a one-shot flame thrower; neither Italy nor Japan had this type of weapon.[23]

Mediumweight Flame Throwers

A disadvantage of the portable flame thrower was the limited capacity of its fuel tanks. During battle they often ran dry, leaving operators with the choice of going to the rear for more fuel or abandoning the weapons. To get around this objection the CWS attempted to increase the capacity.

For the use of Engineer troops in assault operations, the CWS developed a two-man flame thrower. With the exception of the fuel tanks, pressure tank, and minor parts, the design was the same as for the M1 portable. The fuel tanks held twenty-two gallons of fuel, and were fastened on a two-wheeled frame. One operator grasped the handles of the frame and pushed it along like a wheelbarrow, while the other operator carried the flame gun. The fuel charge lasted about thirty seconds, and the range with a mixture of gasoline and oil was around twenty-five yards. The CWS did not produce this flame thrower because the Engineer Board considered it too bulky and heavy for troops.[24]

Another large weapon for assault and mopping-up operations was the cart-mounted flame thrower. The CWS took a fuel pressure unit designed for flame throwing tanks, mounted it on a chemical mortar cart and connected it to a portable flame thrower gun by means of two hundred feet of high pressure hose. The weapon, filled with twenty-five gallons of fuel, weighed more than six hundred pounds. Two men were needed to pull the cart—more if the terrain was rugged. One man remained at the cart while another dragged the flame gun to the firing point. In tests conducted by the Infantry Board the weapon proved efficient and reliable, but too heavy for foot troops in rough country.[25]

The CWS designed a manifold portable flame thrower especially for use in the jungle. By means of a manifold assembly the pressure tanks

[23] (1) German Chemical Warfare Materiel, p. I–P–8. (2) German Chemical Warfare, pp. 141–42.

[24] Rpt, Engineer Board, Demolitions No. 38, Engineering Report on Test of Two-Man Flame Thrower, 1 Jul 43.

[25] Rpt, Infantry Board, Ft Benning, Ga., Cart Mounted Flame Thrower, 28 Sep 45.

and fuel tanks of two or more portable flame throwers could be coupled together. Two hundred feet of hose connected the manifold to a special flame gun. The operator would crawl through the underbrush dragging the gun and hose along with him. With this device one operator could fire as much fuel as six men with portable flame throwers. The CWS developed the manifold flame thrower rather late in the war and it was not produced.

The German Army, like the American, found the small fuel capacity of portable flame throwers a disadvantage, and it devised a larger weapon for its troops. Two men pulled the flame thrower, which weighed more than two hundred pounds and was mounted on a dolly fitted with two pneumatic tires. The fuel tank held approximately eight gallons, sufficient for twenty-five seconds of continuous firing. The range was about thirty yards. The Germans limited the distribution of this weapon, and it was not used to any great extent.[26]

Main Armament Mechanized Flame Throwers

Just as World War II proved the value of portable flame throwers, it likewise demonstrated the usefulness of mechanized flame throwers. The CWS had designed its first mechanized flame thrower in World War I but did not have time to carry the weapon beyond the experimental stage. Intended for installation in a tank, the gun could expel a stream of oil fifty yards. After the war the service put mechanized flame throwers aside and did not work on them again for twenty years.[27]

The revival of the mechanized flame thrower began in the United States in the late 1930's after newspapers, magazines, and newsreels reported that the Italian Army had outfitted some of its armored units with this type of weapon. The Chemical Warfare Technical Committee laid down tentative military characteristics and in the summer of 1940 engineers constructed the weapon. Tests with this flame thrower uncovered flaws which were corrected in a second model, installed in an M2 medium tank. In the tank the flame gun replaced the cannon (the main armament), and for this reason the flame thrower became known as the main armament type. Two sixty-gallon reservoirs on the floor of the tank held fuel, and three commercial steel cylinders held compressed nitrogen for expelling it. Ignition was provided by propane gas lit by sparks from a spark plug. The opera-

[26] German Chemical Warfare, p. 141.
[27] Ray, Incendiaries, pt. III, 190–91.

tor elevated and traversed the gun with his left hand and fired with his right.[28]

With this tank, observers on the Armored Force Board were able to see a mechanized flame thrower in action for the first time. They were not impressed and would not recommend flame throwers for the armored forces.[29] Their opinion, widely shared during the early part of the war, kept the development of mechanized flame throwers moving along at a slow pace. The CWS had to give priority to items that the troops did want, and engineers had difficulty getting tanks for further experiments. The opinion of the Armored Board was based on guesses that seemed reasonable at the time, not on experience. Later, as battle showed the value of flame warfare, opinions changed, but by then the CWS had lost irreplaceable development time.

By the summer of 1942 engineers had the third model, mounted in an M3 medium tank, ready for tests. This flame thrower was provided with a larger fuel supply than previous designs, and used pressure from a rotary pump to expel the fuel. The pump eliminated the need for supplying gas cylinders and removed a potential safety hazard. But the pump took too much power from the tank engine, and the whirling blades of the pump smashed the cellular structure of thickened fuel, thinning it out so that it gave the same range as unthickened fuel. Changing back to compressed air, engineers obtained a range almost twice that of earlier flame throwers.[30]

At the same time the CWS was developing the flame throwing unit for tanks, NDRC engineers had taken up the study of some of the fundamental factors involved in flame throwers such as the design of nozzles and the composition of fuels.[31] In March 1942 the NDRC contracted with several firms for a large flame thrower similar to the Ronson type of the Canadian Army. Several models were made, but none passed beyond the experimental stage. During this period, however, the firms gained experience that later made possible the rapid development of model "Q" (for Quickie). Work on "Q" began in November in the plant of the Standard Oil Development Co. Tanks were so scarce that the designers had to

[28] (1) Charles T. Mitchell, Development of Mechanically Transported Flame Throwers. TDMR 737, 15 Nov 43. (2) CWTC Item 167, Flame Thrower, Development of Mechanically Transported, 16 Jul 40.

[29] Rpt, Armored Board, Project No. 58, Report on Mechanized Flame Thrower, E2, 13 Sep 41.

[30] Mitchell, TDMR 737.

[31] The work of the NDRC on mechanized flame throwers is summarized in (1) *Fire Warfare.* (2) Baxter, *Scientists Against Time,* 294–97. (3) Noyes, *Chemistry,* 420–30.

mount the weapon on an old truck. With napalm thickened fuel, "Q" had a range of more than 100 yards.[32]

By the beginning of 1943 there were thus two fairly satisfactory flame throwers, the CWS model and NDRC's "Q." Although theaters of operation had not asked for main armament flame throwers the Army Ground Forces had watched the development of the weapon with approval. In March 1943 CWS arranged a demonstration to allow the AGF to decide which of the two models it preferred. This turned out to be "Q." The Army decided to place the flame thrower in light tanks, these being the only tanks available.[33]

Engineers mounted the flame gun, fuel reservoir, and compressed gas cylinders in a turret basket that was interchangeable with the regular turret basket of an M5A1 tank. The reservoir held 105 gallons of fuel that could be discharged at a rate of approximately two gallons a second. The range with ordinary fuel was 30 to 40 yards, with thick fuel 105 to 130 yards.[34]

Difficulty in getting tanks delayed the installation of flame throwers, and January 1944 arrived before the Armored Board received a weapon for test. By this time the M5A1 tank was no longer in use, forcing the CWS and NDRC to start over and design a flame thrower for the M4 medium tank. The work went forward slowly because the Army did not want to hold tanks in the United States, the CWS lacked engineers for the project, and considerable time was needed to perfect the complex mechanism. Finally representatives of CWS, AGF, ASF, and NDRC agreed that the fastest way to get a main armament flame thrower into action was to modify the earlier "Q." This was done rapidly, but the M5-4, as the flame thrower was designated, could not be installed until the spring of 1945 because tanks were still scarce. The war ended before the flame throwing tank could be shipped overseas.[35]

[32] The CWS designation for this flame thrower was E7. The "Q" model is discussed in NDRC Div 11, OSRD Report 6012, Development and Field Use of E7-7 Mechanized Flame Thrower, 12 Sep 45.

[33] (1) Ltr, Hq SOS to CG ASF, 24 Jan 43, sub: Military Characteristics for Mechanically Transported Flame Thrower, with two inds. SPRMD 470.71. (2) Memo, Munitions Development Div for CG CWS Tech Cmd, 30 Mar 43, sub: Report of Conference on Mechanized Flame Thrower. Proj 8.1 (FY 43) in Corres Files, CW Labs A CmlC, Md.

[34] (1) Development and Field Use of E7-7 Mechanized Flame Thrower, NDRC Div 11, Report No. OSRD 6012, 12 Sep 45. (2) Flame Thrower, Mechanized, E7-7, in Light Tank, M5A1. NDRC Div 11, Report No. OSRD 5125, 29 May 45.

[35] (1) Report of Activities of the Technical Division, p. 143. (2) Memo, Lt Col R. A. Meridith, ADG Asst Ground AG for CofS US Army, attn: G-4 Division, WDGS, sub: Mechanized Flame Thrower, 10 Oct 44. In AGF file 470.71.

The CWS in the meantime had on its hands four obsolete light tanks that it had rigged up with flame throwers for Armored Board tests. The service did not wish to abandon these tanks since they were serviceable as flame weapons. It had the turrets strengthened and shipped the tanks to Manila early in 1945. The Sixth Army attached them to the 27th Division for assault operations on Myoko Mountain, and to the 38th Infantry Division in the Ipo Dam area. They were the only main armament flame throwers produced in continental United States to see combat.[36]

Main Armament Flame Throwers Produced in Hawaii

Troops in the Pacific early discovered the value of flame throwers in overcoming fortified positions. By 1944 experience with flame warfare convinced them of the need for main armament flame throwing tanks. The weapons were not available for the reasons noted above and servicemen in the Central Pacific Area produced their own.

The main armament flame thrower turned out in Hawaii was based on the Ronson flame thrower. The Ronson had been developed in Great Britain in 1941, rejected by the British Army because of its short range and low hitting power, and then accepted by the Canadian Army and produced in Canada. The Canadians sent twenty to the Pacific at the request of the V Marine Amphibious Corps. In January 1944 a team of men from the 43d Chemical Laboratory Company, the Royal Canadian Army, and the V Amphibious Corps installed a Ronson in an LVT, and on 3 February demonstrated it at Koko Head before high-ranking Army, Navy, and Marine Corps officers. The weapon satisfied the officers, who decided that it should be developed further. Shortly thereafter the Marine Corps stepped aside, leaving Col. George H. Unmacht, CWS, responsible for future work.[37]

The medium tank, rather than the LVT, was the most suitable mount for the Ronson, but as in other instances, medium tanks were needed for their high explosive firepower and were scarce. Only the obsolescent M3A1 light tank could be obtained from Ordnance. The 43d Chemical Labora-

[36] (1) McKinney, Mechanized Flame Thrower Operations, pp. 142–50. (2) *Sixth United States Army, Report of the Luzon Campaign, III,* p. 89.

[37] For the part played by the CWS in developing flame throwing tanks in the Pacific see: (1) History of Chemical Section, U.S. Army Forces Middle Pacific, 7 Dec 41–2 Sep 45, vols. II and III, in OCMH; (2) Col George H. Unmacht, "Flame Throwing Seabees," *Armed Forces Chemical Journal,* III (July 1948), 48–50, reprinted from *United States Naval Institute Proceedings* (April 1948).

tory Company removed the 37-mm. cannon from a tank and replaced it with a flame gun, protected by a howitzerlike shroud. To lessen the possibility of mechanical failure and to permit easier operation, the company redesigned the entire electrical system. The Honolulu Iron Works fabricated the fuel reservoirs. Satan, as the finished tank was called, used compressed carbon dioxide as the propellent gas, had a fuel capacity of 170 gallons, and a range of 40 to 60 yards with oily fuel or of 60 to 80 yards with thickened fuel. It was demonstrated on 15 April before Army, Navy, and Marine officers, and the following day Lt. Gen. Holland M. Smith asked for twenty-four Satans.

In June on Saipan, marines employed the Hawaiian flame throwers for mopping up and, after the operators gained experience, in assaults. The tanks attacked dugouts, cane fields, buildings, and caves. Marines then shipped the tanks to Tinian and used them in the assault waves and in overcoming Japanese strongholds.[38]

These two islands served as proving grounds for the tank mounted flame thrower, and brought out faults in the design. The scarcity of napalm restricted the weapons to oily fuel, which gave a shorter range than marines wanted. Before the weapons were employed again, Colonel Unmacht's group overcame some of the flaws, and the supply channels opened to the flow of napalm.

In September the Tenth Army, planning an attack—later canceled—on Formosa, requested that large capacity flame throwers be installed in fifty-four M4 medium tanks. In the first model the company installed a Ronson gun like that used on Satan. The Tenth Army pointed out that the silhouette was different from the 75-mm. gun of the regular M4 tank, and this would permit the enemy to spot flame tanks. The problem then arose of obtaining 75-mm. gun tubes to enclose the flame gun. Ordnance did not wish to sacrifice new tubes for the manufacture of flame throwers, and only a few salvaged tubes were available. Seabees machined these items to hold the flame gun, and in the meantime the ASF shipped fourteen salvaged tubes under high priority. Later, Colonel Unmacht obtained authority to use forty-two serviceable tubes for the purpose.

The new flame thrower tank, designated POA-CWS "75" H-1 (POA for Pacific Ocean Areas, H for Hawaii), was demonstrated to the Tenth

[38] (1) McKinney, Mechanized Flame Thrower Operations, pp. 75–78. (2) Maj Carl W. Hoffman, "Marine Corps Monographs," *The Seizure of Tinian* (Washington, 1951), pp. 53, 131. (3) Maj Carl W. Hoffman, "Marine Corps Monographs," *Saipan: The Beginning of the End* (Washington, 1950), pp. 146, 252, 254.

Army about 1 November. The weapon used compressed carbon dioxide gas to propel the fuel, had a fuel capacity of 290 gallons, a range of 40 yards with oily fuel and 60 to 80 yards with thickened fuel. Eight tanks were sent to the Fleet Marine Force, Pacific, for the Iwo Jima operation and 54 were supplied to the 713th Provisional Flame Thrower Tank Battalion for the Ryukyus operation.

On Iwo Jima, marines found the flame tanks particularly helpful in the later stages of the operation when they had to take a network of caves. By the time the marines had reached the northern end of the island, flame tanks had proven so useful that demands for them exceeded the supply. On Okinawa the operations took place on the hilly southern portion of the island where Japanese troops had defenses in cliffs, hills, and escarpments. The tank battalion carried out more than six hundred attacks, and fired almost 200,000 gallons of napalm thickened fuel.[39]

Troops on Okinawa employed an ingenious hose extension against caves that were out of range of tanks. The Navy donated fifty-foot lengths of fire hose which the men coupled together to form a hose four hundred feet long. They fastened one end of the hose to the fuel reservoir of the tank, and attached an M2-2 portable flame gun to the other end. In action the tank parked as close as possible to the target, the operators dragged the hose to a position within range, the tank pumped fuel through the hose, and the nozzleman ignited the fuel and directed the flame at the target. The extension was used with good results on a number of occasions.[40]

Troops objected to main armament flame throwers chiefly because they replaced the tank's cannon. To meet this criticism, Colonel Unmacht's staff drew up plans for mounting flame throwers alongside the cannon instead of replacing it. Work began in late 1944 when Fleet Marine Force, Pacific, anticipating an invasion of Japan, asked for at least seventy-two main armament flame throwers. Most of the tanks provided by the marines carried 75-mm. guns. The remainder carried 105-mm. howitzers. By judicious planning, designers arranged the interior of the vehicles to allow

[39] (1) McKinney, Mechanized Flame Thrower Operations, pp. 93–104, 108–39. (2) Maj Charles S. Nichols, Jr., and Henry I. Shaw, Jr., "Marine Corps Monographs," *Okinawa: Victory in the Pacific* (Washington, 1955), pp. 132, 272. (3) Appleman, Burns, Gugeler, and Stevens, *Okinawa: The Last Battle*, pp. 229, 256–57, 277, 305, 340, 456. (4) Alvin P. Stauffer, *The War Against Japan*, UNITED STATES ARMY IN WORLD WAR II (Washington, 1952), p. 405.

[40] (1) McKinney, Mechanized Flame Thrower Operations, pp. 119–21, 124–25, 139–42. (2) Nichols and Shaw, *Okinawa*, p. 247. (3) Appleman, Burns, Gugeler, and Stevens, *Okinawa*, pp. 441–42, 444.

M4 MEDIUM FLAME-THROWER TANK *in action on Okinawa, May 1945*

the storage of forty rounds of 75-mm. or twenty rounds of 105-mm. shells without decreasing the quantity of flame-thrower fuel. Handicapped by a scarcity of parts and a dearth of machinists and other craftsmen, the work proceeded slowly. During the battle on Okinawa the Tenth Army asked for eighteen of these tanks. They were on their way to that island by the time the battle ended, and were rerouted, instead, to the Marianas to equip the Marine division rehabilitating there. Seventy tanks were ready for the invasion of Japan when the operation was called off and the war came to an end.

The Marine Corps was not alone in using mechanized flame throwers. The Navy, after seeing a demonstration of model "Q" in December 1943, recognized the effectiveness of flame throwers in amphibious assaults. In January 1944 the Bureau of Ordnance ordered a model mounted on an LCVP or LCM. The complete unit, designated the Navy Mark I flame thrower, had a fuel capacity of 300 gallons and a maximum range of approximately 110 yards with napalm thickened gasoline. The unit proved too heavy for an LCVP and the Chemical section at Pearl Harbor tried mounting it in an M3A5 tank. But the excessive weight (which reduced the mobility of the tank), the limited flame gun traverse of 60°, and other

LT. GEN. WILHELM D. STYER *standing in front of a flame thrower mounted on a medium tank chassis at Schofield Barracks, Hawaii. To the right of General Styer is Col. Jay C. Whitehair, Howard C. Peterson, and Col. George F. Unmacht.*

difficulties ended the experiment. Finally an LVT-4 lightly armored amphibious tractor was found to be a fairly satisfactory mount. Six of these were used in the mopping-up phase of the Peleliu operation, particularly around the caves of Umurbrogol mountain. The LVT-4 was not the ideal carrier and the crews were kept busy making repairs but the flame thrower itself proved rugged and dependable.[41]

Under Colonel Unmacht the composite group of Army, Navy, and Marine personnel produced more main armament flame throwing tanks than did engineers in the United States, but the problems which they faced were much simpler. The Army, Navy, and Marine Corps in the Pacific were anxious to get the weapons and gave the Chemical section all necessary assistance and supplies, whereas Edgewood could not get the Army to set up a requirement for a main armament flame thrower and had great diffi-

[41] (1) The Navy Mark I is described in: Summary Technical Report of Division 11, NDRC, vol. 3, *Fire Warfare*, pp. 112–16. (2) Maj Frank O. Hough, "Marine Corps Monographs," *The Assault on Peleliu* (Washington, 1950), pp. 32, 180–81. (3) Smith, *The Approach to the Philippines*, p. 564.

culty obtaining tanks for conversion into flame throwers. American forces on one side of the world wanted the weapon, gave technicians full support, and got it. Forces on the other side of the world were indifferent toward the weapon, gave technicians little support, and did not receive it.

Enemy armies had mechanized flame throwers, but used them infrequently. Indeed, there is no record of Italians or Japanese using flame tanks against United States troops. The Italians had had tank mounted weapons since the Ethiopian War, 1935–1936. The tank was quite light and mounted the flame gun coaxially with a machine gun. Fuel was carried in a trailer with a capacity of one hundred gallons. The range was rather low, from thirty to forty-five yards. The reasons why the Italians did not employ their tanks are not known. Among them may have been the lack of opportunity, unfamiliarity with flame thrower tactics, and conservatism of tank commanders.[42]

American troops did not see Japanese flame throwing vehicles until they captured eight on Luzon in 1945. The weapons were placed on amphibious tractors, similar to American DUKW's. The Japanese did not have fuel thickeners comparable to American napalm, and had to use mixtures of crude oil, gasoline, and kerosene. Since Japanese troops employed portable flame throwers against Americans from early 1942 onward, it is difficult to explain why they did not use mechanized flame throwers. American troops learned by trial and error of the value of flame tanks, and perhaps the Japanese never threw off their conservatism sufficiently to give the tanks full-scale battle tests.[43]

The German Army was equipped with a Pz. Kw. III tank carrying a flame gun disguised as a cannon. The fuel capacity was more than 200 gallons, the range about 40 yards. In addition the Germans had armored half-track vehicles carrying 2 large flame throwers on the sides and a small flame thrower at the rear. Each large flame thrower had a fuel reservoir of 95 gallons, and a range of 40 yards. The Germans also developed a trailer-mounted flame thrower that could be hauled behind a truck or tank. The 2-wheeled trailer carried a 40-gallon fuel reservoir, and was protected by armor plate. Only a few of these were ever manufactured. German flame fuels did not have particularly good thickening agents. The best was aluminum alcoholate, but this was not as good as napalm. Generally German

[42] (1) McKinney, Portable Flame Thrower Operations, p. 34. (2) WD Intel Bull, Oct 42, pp. 67–68.

[43] (1)McKinney, Portable Flame Thrower Operations, pp. 32–33. (2) WD Intel Bull, Sep 45, pp. 114–17.

thickened fuels had little more, if any, range than American unthickened fuels.[44]

Auxiliary Mechanized Flame Throwers

The auxiliary mechanized flame thrower was smaller than the main armament type, and at the most replaced only a machine gun in the tank. Since the tank retained its cannon, tank commanders did not raise as strenuous objections to the auxiliary flame thrower as they did to the main armament type. Warfare on the Pacific islands provided the impetus for the development of the auxiliary flame thrower. After the Battle of Guadalcanal infantrymen and marines tried to devise ways of putting portable flame throwers in tanks so as to protect the operator from Japanese rifle fire. One group of soldiers drilled a hole in the armor of the tank near the bow machine gun and shoved through a flame gun. They fired the flame thrower, and then ignited the fuel by means of tracers. The 3d Marine Division modified a flame gun to fit the bow machine gun ball-and-socket joint. For the invasion of Kwajalein the 7th Infantry Division mounted flame throwers on LVT's and on light tanks. None of the improvised mountings were successful until February 1944 at Bougainville when tanks carrying portable flame throwers supported an infantry assault against Japanese positions along the Torokina River.[45]

The idea of installing portable flame throwers in tanks was sound. The difficulty lay in the short range, small fuel capacity, and delicacy of the weapon which had not been designed to withstand the jarring vibration of tanks. Because troops constantly tried to improvise auxiliary flame throwers, the Army Service Forces in October 1943 requested the CWS to develop a standard model. Service engineers took the portable flame thrower and modified it to fit the bow machine gun ball-mount. Fuel reservoirs were designed for M3, M4, and M5 tanks. It took troops in the field several hours to install fuel reservoirs, but thereafter the operator could remove the machine gun and insert the flame gun in a minute or two. The flame thrower could fire a gallon of fuel per second to an effective range of 25 to 30 yards with oily fuel, 50 to 60 yards with thickened

[44] (1) German Chemical Warfare, pp. 142–43, 153–55. (2) McKinney, Mechanized Flame Thrower Operations, pp. 194–95, 200. (3) WD Intel Bull, Jul 44, pp. 11–14. (4) Tactical and Technical Trends, no. 45, 1 Apr 44, pp. 7–14, a publication of Intel Div, WD. (5) Chemical Warfare Bulletin 30, p. 11, Aug–Oct 44.

[45] (1) Philip A. Crowl and Edmund G. Love, *Seizure of the Gilberts and Marshalls,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1955), p. 233. (2) McKinney, Mechanized Flame Thrower Operations, pp. 2–8.

M3A1 LIGHT TANK EQUIPPED WITH FLAME GUN *firing during a demonstration, New Zealand, October 1943.*

fuel. The CWS procured 1,784 model M3-4-3 bow flame throwers with fuel capacity of 50 gallons for M4 tanks, and 300 model E5R2-M3 with a capacity of 10 gallons for M3 or M5 tanks. Many bow-type flame throwers saw action in the European Theater, in the Marianas operation, on Peleliu, Luzon, and other islands.[46]

Tank commanders were not all in favor of the bow flame thrower because it deprived them of an important machine gun. An alternative was to mount the flame gun in the turret alongside the periscope. The CWS and its contractors produced several periscope models, one of which (M3-4-E6R3) went into production in 1945 too late for war use.[47]

The Italian and Japanese Armies did not equip tanks with auxiliary flame throwers, but the German Army had two flame throwers that might be placed in this classification. For the Pz. Kw. II tank it developed a

[46] (1) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 24. (2) TM 3-362, Jun 45. (3) Finkelstein, Flame Throwers, pp. 261-89. (4) McKinney, Mechanized Flame Thrower Operations, pp. 10-74. (5) The E4-5, E4R2-5R1, and E4R3-5R1 models occasionally mentioned in reports were prestandardization models of the M3-4-3, without one of the fuel reservoirs.

[47] (1) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 24. (2) Finkelstein, Flame Throwers, pp. 384-431. (3) TM 3-364, 6 Jun 45.

FLAME GUN TO FIT .30-CAL. MACHINE GUN MOUNT *of tanks is demonstrated to Seventh Army soldiers, France, February 1945.*

small flame thrower mounted in an individual turret. Tanks carried two of these turrets on the bow. Behind each turret was a small cylinder of acetylene for ignition and a large reservoir for thirty-five gallons of fuel. Electrical controls for traversing the turrets and firing the flame throwers were in the tank. The weapons could fire eighty bursts, each lasting two to three seconds, a distance of thirty-five yards. For the Pz. Jg. 38 tank the Germans provided a projector flame gun similar to the portable *Flammenwerfer 41.* The fuel was held in three reservoirs with a capacity of 154 gallons, and was pumped to the gun by a gasoline engine. The weapon could fire twenty-four bursts, which was the number of cartridges carried in the ignition magazine. The German Army seems to have made little use of auxiliary flame throwers.[48]

Auxiliary Flame Throwers Made in Hawaii

Marines and infantrymen in the Pacific had hastened the development of auxiliary flame throwers and they were anxious to obtain the weapons.

[48] (1) Tactical and Technical Trends, no. 39, 2 Dec 43, pp. 9–11. (2) German Chemical Warfare Materiel, pp. I–P–15, I–P–16. (3) German Chemical Warfare, p. 142.

Finally in 1944 the Tenth Army could wait no longer for weapons to come from the States. It asked the Chemical Section, USAFPOA, then engaged in producing main armament flame throwers, to provide at least eighty-eight periscope flame weapons. Colonel Unmacht's composite group constructed a model based on an experimental periscope flame thrower gun manufactured by the Armored Board at Fort Knox, which in turn had been based on the M1A1 portable flame thrower gun. The gun was constructed from a piece of metal tubing, and passed through a 1½-inch hole in the periscope ring. The fuel reservoir developed by technicians at Edgewood for the bow auxiliary flame thrower was used when it was available, but when it was not similar containers were manufactured at Pearl Harbor. Compressed air or nitrogen was used as the propellant. With unthickened fuel the range was twenty yards; with thickened fuel, twice that distance. The weapon could be mounted in any of the M4 medium tanks.[49]

One hundred and seventy-six of these were completed for the Tenth Army. They were on hand for the Okinawa and Iwo Jima campaigns, but they were not used extensively because Hawaiian-produced main armament flame throwers, preferred for their large fuel capacity and greater range, were also available for these battles.[50]

The demand for auxiliary flame throwers waxed and waned during the war. When the Army first used them in 1944, troops in the Pacific liked them because they had a longer range and carried more fuel than the portable flame thrower, and because armor allowed the flame thrower operator to approach Japanese positions without fear of rifle fire. But when Hawaiian main armament flame throwers became available and troops had an opportunity to compare the auxiliary and the main armament in battle, their choice swung toward the latter type with its larger fuel capacity, greater range, and all-around mobility. By the end of the war the CWS and NDRC were concentrating their efforts on the development and production of large main armament weapons rather than small auxiliary models.

[49] (1) A full account of the development of the auxiliary flame thrower in Hawaii may be found in: History of Chemical Section, U.S. Army Forces Middle Pacific, 7 Dec 41–2 Sep 45, vols. II and III. (2) Tentative Instruction Book for Flame Thrower, Mechanized POA–CWS Periscope H (E4R2) A–H1A and H1B, prepared by CWS Central Pacific Base Command, 24 Feb 45, ETF 550–344. (3) CW Supply Catalog, List of Service Parts and Spare Parts for Flame Thrower, Mechanized, POA–CWS Periscope H (E4R2) A–H1B, prepared by Hq Central Pacific Base Command, 1 Jul 45, ETF 550–484A.

[50] McKinney, Mechanized Flame Thrower Operations, pp. 15–21.

Incendiary Projector for Airplanes

In 1941 CWS engineers made some experiments to see if a flame thrower could be mounted on an airplane. They constructed a model and tested it on the ground. The turbulent blast of air from the propeller extinguished the flame and the CWS dropped the project. Late in 1943 the Army Air Forces requested the service to resume work. It was reasoned that a rain of burning thickened fuel dropping from the sky might be used to set fire to enemy-held jungle, grassy areas, and supply dumps. At this time the British were working on an airplane flame thrower and the CWS profited from their experience. CWS and NDRC engineers designed a fuel container of the size and shape of the 4,000-pound bomb, fitting it with a discharge pipe and nozzle similar to that used on toxic spray tanks. Rocket motors provided gas that expelled the 210-gallon load of thickened gasoline in one spectacular burst. Technicians tested the projector, aeroflame, as the weapon was called, on a wooden tower and in actual flight on B–25H airplanes. Although the aeroflame developed into a workable weapon, the CWS decided that droppable gasoline tanks were more effective in starting fires, and in 1944 it stopped the project for good.[51]

Emplaced Flame Throwers

After Dunkirk, Britain's eastern coast lay vulnerable to invasion. As part of the defenses against German landings the Petroleum Warfare Department installed flame throwers along the Channel beaches. From underground storage tanks holding forty-five tons of fuel—a mixture of gasoline, kerosene, and diesel oil—pipes led outward beneath the sea. Valves on the ends of the pipes could be opened by remote control, releasing oil which floated to the surface. Ignited by naval flares, the pools of oil would burn fiercely for hours. The British also emplaced flame throwers along roads to burn enemy vehicles and troops that might get ashore.[52]

Taking their cue from the British, the CWS developed a remote controlled flame thrower to be used to guard U.S. airfields and beaches. The steel fuel tank holding 120 gallons of oil could be placed in a pit along with two cylinders of compressed nitrogen. Pipes led above ground to 2 flame thrower nozzles. The nozzles pointed in opposite directions, and threw streams of burning oil 40 yards. A wall of flame 80 yards long,

[51] T. Loew and C. T. Mitchell, Development of Incendiary Projector for Airplanes. TDMR 909, 23 Oct 44.

[52] WD Intel Bull, Apr 46, pp. 39–44.

lasting about a minute and a half, could be set up. The CWS standardized the device in 1941, but the Army found no use for it and discarded it at the end of the war.[53]

The first recorded use of emplaced flame throwers was by the Russians in the defense of Moscow. A line of flame throwers was set up in the outer defense zone that the Soviets had built in front of their capital to block the German Army. The body of the flame thrower was a cylindrical tank twenty-one inches high, twelve inches in diameter, and holding eight gallons of oil. Pressure was furnished by gas given off from burning powder. These flame throwers were dug in at intervals of about thirty yards and covered with stones, earth, or other natural materials as camouflage. Detonated electrically the weapon threw out a stream of flame lasting a second or two. When the Germans went on the defensive they employed emplaced flame throwers similar to the Russian type. The Japanese in Burma set up some field expedients, but these were of little value.[54]

The British flame weapons emplaced along the channel might have been useful barriers to an invasion, but the Russian and German weapons of this type probably had only a temporary psychological effect since they suffered from a limited range and fuel capacity. Furthermore, there was considerable labor in digging them in, the aim could not be changed once they were emplaced, they could only be fired once, the enemy might bypass them, and their control wires could be easily damaged by shell fire. On the whole, World War II experience showed that the emplaced flame thrower had only slight value in warfare.

Servicing Flame Throwers

The job of the CWS did not end with the production of flame throwers. Weapons had to be serviced, fuels had to be mixed with thickeners, and compressed gas or air had to be supplied. The CWS rigged up an air compressor and mixing vat carried on a truck or trailer. With this equipment troops could mix the hundreds of gallons of thickened fuel used by flame tanks, and compress the large volume of air needed as a propellant.[55]

[53] (1) CWTC Item 356, Emplaced Flame Thrower, 22 Jul 41. (2) CWTC Item 1513, Obsoletion of Flame Thrower, Emplaced, M1, 30 Dec 45. (3) CWTC Item 1564, same title, 28 Mar 46.

[54] (1) Tactical and Technical Trends, no. 26, 3 Jun 43, pp. 24–26. (2) WD Intel Bull, Nov 44, pp. 80–85. (3) *Ibid.*, Apr 46, pp. 39–44.

[55] (1) Mobile Flame Throwing Servicing Unit, 43d CWS Chem Lab TR 40, 18 Jul 44. (2) TM 3–361, 26 Jun 45. (3) CWTC Item 1487, Standardization of the Flame Thrower, Mechanized, M5–4, and the Service Unit, Mechanized Flame Thrower, M4, 4 Oct 45.

Portable flame throwers did not require as much fuel and propellant as mechanized types, but nevertheless problems existed. While napalm and gasoline could be carried in cans and mixed when needed, a machine weighing 800 pounds was required to furnish compressed air. Such a compressor could be carried only on a jeep or truck. The CWS decided to develop a small, light, gas producer. With co-operation of the NDRC, it turned out a generator weighing sixty pounds and containing lithium hydride. When water was allowed to drip on the compound, hydrogen under a pressure of 2,000 pounds per square inch was evolved. This hydrogen could be piped into flame thrower gas tanks. The service started producing these generators in the spring of 1945, and a few reached the theaters before the end of the war.[56]

Toxicology of Flame Attack

A year after the initial operations in the Pacific the CWS began studies to discover the predominating characteristics and cause of death by flame and to learn what defensive measures might be devised against the use of flame by the enemy. The agencies engaged in various aspects of flame attack research with the CWS included NDRC units at the Massachusetts Institute of Technology, the Standard Oil Development Co., New York University, Harvard and Johns Hopkins Medical Schools; units of the Bureaus of Ordnance and Medicine of the Navy Department, the Armored Medical Research Laboratory; and the Experiment Station at Suffield, Canada.[57]

In studying the toxicology of flame attack in poorly ventilated enclosed spaces like those found in Japanese bunkers and similar fortifications, researchers determined that three important changes occurred within them at the moment of flame attack, quite aside from the penetration of the flaming fuel itself: there was a sudden jump in temperature, lethal concentrations of carbon monoxide were built up in the bunker, and there was a dangerous lowering of oxygen content. They learned that 70 percent carbon monoxide in the blood resulted in unconsciousness and frequently in death and that this accumulation was obtainable in flame attack within two minutes. Furthermore, only one-tenth of one percent

[56] (1) TM 3-374, 7 Jul 45. (2) CWTC Item 1398, Standardization of Generator, Hydrogen, High-Pressure, Portable, M1 and Cartridge, Hydride, Hydrogen Generator, M1, 2 Aug 45.

[57] Misc Rpt, Informal Notes of Meeting on Flame Throwers held at the Medical Research Laboratory, Edgewood Arsenal, 17 and 18 July 1944. MDF 109.1 Tech Lib, A CmlC, Md. (2) Noyes, *Chemistry*, pp. 258-59. (3) "CWS Studies Flame Deaths," *Chemical Warfare Bulletin* 30 (Apr-May 44), 31-32.

carbon monoxide in the air was sufficient to maintain this lethal blood level, and it was present in bunkers for seven to ten minutes after flame attack. They also learned that for intervals up to fifteen seconds there was almost complete absence of oxygen in a bunker under attack, and that unconsciousness would likely be almost instantaneous in such an event. Any one of these factors or any combination of them, therefore, meant certain death, quite aside from the effects of direct contact with the flame.[58]

Work on flame defense led to the construction of a hood-type mask built to withstand 1,000° F. for one minute, to the development of a steel sliding door for pillbox apertures, to experimental fireproof clothing and water fog, and to spray extinguishers, all of which proved unsatisfactory. The CWS finally concluded that no positive defense could be devised against flame attack.[59]

Flame throwers were not major weapons in the same sense as cannon, rifles, and bombs. Rather they were weapons that proved valuable in certain tactical situations. The men in the Pacific, the locale of most of these situations, did much to bring about the improvement of flame throwers. Americans started work on them later than Europeans and Japanese, but while enemy armies did not push the development of the weapon, Americans, particularly in the Pacific, called for it more and more frequently as the war progressed. Despite the fact that the American achievement in flame thrower development and production does not look impressive, it surpassed that of the enemy during the same period.

[58] "Toxicology of Flame Attack in Enclosed Spaces" and "Toxicology of Carbon Monoxide and Anoxia," in Symposium on the Toxicological Aspects of the Flame Thrower, Dumbarton Oaks, 29 Jan 45. ETF 235-45.

[59] (1) MIT MR 136, Protection Against Flame Throwers, 12 May 45. (2) CWS R & D Program Monthly Report, FY 1945, Jun 45, p. 63.

CHAPTER VIII

Incendiaries

In 1917–18 the Chemical Warfare Service branched out from its research on toxic agents into other fields, one of which was incendiary mixtures. Chemists experimented with incendiary fillings for shells, grenades, and bombs, but did not have time to perfect any of the munitions.[1] In this field CWS overlapped the Ordnance Department's work on incendiaries. In 1920 the War Department set up a line of demarcation between the two services, with the Ordnance Department henceforth to design the munitions and the CWS to provide the filling.[2]

During the 1920's and early 1930's the CWS practically ignored incendiaries. In the first place, they had not been very effective in World War I, and there was no indication that they would be in the future. Secondly, there was a widespread feeling that high explosives were better. An Ordnance Department study, written in 1934, stated that "everything that can be accomplished by an incendiary bomb can in most cases, at least, be accomplished as well or better by either a smoke bomb loaded with WP [white phosphorus] or demolition bomb loaded with a high explosive."[3] Along the same line, Maj. Gen. Amos A. Fries had said in the Report of the CWS, 1922, "Purely incendiary materials are generally of much less importance [than smoke]." Thirdly, lack of funds forced the CWS to leave out of its research programs all but the most vital projects—and, as noted, incendiaries did not seem important at the time. Finally, the division of

[1] (1) Fries and West, *Chemical Warfare,* pp. 336–44. (2) Ray, Incendiaries.

[2] WD GO 54, Sec IIIc, 28 Aug 20.

[3] From a study on the relative effectiveness of incendiary and demolition bombs by Maj H. H. Zornig, OD, 17 Jan 34, quoted in A. L. Kibler, Brief Review of Work Done to Date on Incendiaries. ETF 180–2, 10 Apr 34.

responsibility between the CWS and Ordnance was unfortunate in one respect—neither service felt as enthusiastic about the development of incendiaries as it would have if given sole authority.[4]

The unrest abroad in the mid-thirties revived interest in incendiary bombs. In 1935 a reporter on the New York *Herald Tribune* covering the Italian invasion of Ethiopia found a partially burned bomb that had been dropped by an Italian plane. He shipped it back to his newspaper, which gave it to Professor Joachim E. Zanetti of Columbia University, a CWS reserve officer. Zanetti passed it on to the CWS, which then analyzed it.[5] In the summer of 1936 Maj. Gen. Claude E. Brigham sent an officer to Europe to gather information on incendiary bombs. In December of that year, the CWS added an incendiary project to its program, and chemists began experiments. These experiments provided them with the experience and data that were to prove extremely useful when the service began to produce incendiaries a few years later.

Incendiary Bombs

One-Hundred-Pound Bombs

The earliest American incendiary bomb of World War II was the 100-pound missile, M47. It began in a roundabout way in 1937 when the GHQ Air Force asked the Ordnance Department for a chemical bomb.[6] Ordnance completed the munition in 1940. At this time the armed forces had no incendiary bomb, and as an emergency measure the Ordnance Department recommended that the new chemical bomb be pressed into use as an incendiary, by loading it with gasoline and cotton waste.[7] While the idea seemed good, tests conducted by the CWS showed that ordinary gasoline was almost useless as a filling. When bombs exploded the gasoline atomized and burned out so quickly that it scarcely had time to transfer heat and fire to the target. A material was needed to thicken the gasoline so as to make it burn slowly.

[4] Green, Thomson, and Roots, *Planning Munitions for War*, pp. 259, 452.

[5] L. Wilson Greene, "Prewar Incendiary Bomb Development," *Armed Forces Chemical Journal*, II (October 1947), 25–30.

[6] Ltr, CG GHQ Air Force to TAG, 2 Jul 37, sub: 100-lb Chemical Bomb. Cited in Ordnance Technical Committee Minutes (hereafter cited as OCM) 16808.

[7] (1) Green, Thomson, and Roots, *Planning Munitions for War*, pp. 455–56. (2) Bomb, Chemical, 100-lb, M47, Classified as Standard, 3 Oct 40. OCM 16142. (3) Bomb, Chemical, 100-lb, M47, Incendiary Filler, Approval of, 20 Nov 40. OCM 16274.

Overseas the British were adding rubber to the gasoline in bombs, making a filling resembling sticky rubber cement. Following the lead of the British the CWS adopted smoked rubber, crepe rubber, and latex as thickeners, designating the respective fillings as incendiary oil SR, incendiary oil CR, and incendiary oil LA.[8]

With the advance of Japanese armies in Southeast Asia cutting the flow of natural rubber to the United States, the CWS and NDRC made a wide search for substitute thickeners. Two lines of research led to success. Chemists at Du Pont found that isobutyl methacrylate polymer, (IM), converted gasoline into a tough, rubbery jelly. Unfortunately a large amount of IM—from 15 to 20 percent—was necessary to thicken gasoline to the required point, and IM was in short supply. Plastic firms were using it to make transparent bomber noses and other war items. The CWS had to find materials that could replace part of the IM without impairing the desirable properties of the filling.[9]

While experiments were going on with IM, NDRC chemists at Arthur D. Little, Inc., and Harvard University had taken a different tack and were investigating soaps as thickeners. Such an investigation had been carried out by CWS chemists in World War I but without much success. Their gasoline-soap mixtures had been hard and friable, lacking the adhesiveness and cohesiveness demanded in a gasoline incendiary filling.[10] The new generation of chemists was more fortunate, coming up with an aluminum soap of naphthenic and palmitic acids that converted gasoline into a thick jelly suitable as an incendiary. The men named it napalm from *na*phthenic and *palm*itic. Gobs of napalm thickened gasoline, scattered by the explosion of a bomb, clung to many surfaces and burned fiercely for several minutes. The mixture was as effective as rubber thickened gasoline. Furthermore napalm could be used to thicken gasoline for flame throwers, greatly increasing the range.[11]

[8] (1) CWTC Item 425, Incendiary Fillings for M47 100-lb Chemical Bomb, 16 Dec 41. (2) CWTC Item 457, same title, 10 Feb 42.

[9] (1) Gaul and Finkelstein, Incendiaries, pp. 145–62. (2) Report of Activities of the Technical Division, pp. 39–43.

[10] (1) Arthur B. Ray, "Incendiaries in Modern Warfare," *Industrial and Engineering Chemistry,* 13 (1921), 645–46. (2) Ray, Incendiaries, pp. 33–57.

[11] (1) Louis F. Fieser, George C. Harris, E. B. Hershberg, Morley Morgana, Frederick C. Novello, and Stearns T. Putnam, "Napalm," *Industrial and Engineering Chemistry,* 38 (1946) 768–73. (2) Louis F. Fieser, U.S. Patent 2,606,107, Incendiary Gels. (3) E. W. Hollingsworth, "The Use of Thickened Gasoline in Warfare," *Armed Forces Chemical Journal,* IV (January 1951), 26–32. (4) R. W. Hufferd "Spectacular Developments Made in Incendiaries," *Chemical Engineering,* 53 (1946), 110–13. (5) Summary Tech Rpt Division 11, NDRC, pp. 192–226. (6) Noyes, *Chemistry,* pp. 410–19.

Now the CWS possessed two thickeners, IM and napalm. It had to decide how much of each material to purchase. Firms which had begun to manufacture napalm were having difficulty producing satisfactory, uniform batches. The thickener IM, on the other hand, was hard to obtain in competition with aircraft manufacturers and other war industries. The Army settled the question by allotting most of the IM elsewhere, leaving the CWS and its contractors to overcome the problems holding up the manufacture of napalm. By January 1943 only one manufacturer was in full-scale production, but at the end of the year nine other companies had joined in. From 500,000 pounds in 1943, production jumped to 8,000,000 in 1944 and 12,000,000 in 1945.[12]

Finding a thickening agent for the gasoline filling was not the only difficulty in developing the M47 100-pound bomb. The casing had to be modified in several ways before the war was over. Originally the specifications called for walls one thirty-second of an inch thick. After a number of bombs had been made the CWS and the Ordnance Department discovered that the metal was too thin to withstand rough handling. New specifications doubled the wall thickness, the missile being redesignated as M47A1.[13] When bombs were filled with mustard, moreover, the agent for which they had originally been designed, pressure from gaseous decomposition products sometimes split the welds. Since the CWS had to keep a supply of mustard filled bombs on hand for retaliation in case of enemy chemical attack, the seams had to be strengthened. About the same time a problem arose with incendiary fillings. Bomb interiors were coated with acid-proof paint to protect them from corrosion by mustard. Evidence accumulated that this paint was affecting thickened gasoline. Bombs with thicker welds and without the acid-proof paint, designated as M47A2, were then turned out and saw action until the end of the war.[14]

During the conflict the CWS procured three and a half million M47-type bombs. Although referred to as 100-pounders, their total weight, including forty pounds of incendiary filling, was only seventy pounds. Japan and Germany each felt the flaming burst of more than one-half million missiles. In one attack on the Focke-Wulf aircraft plant at Marienburg,

[12] (1) See below, pp. 350–52. (2) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[13] OCM 18706, 27 Aug 42, cited in CWTC Item 1275, Standardization of Bomb, Incendiary, 100-lb, AN–M47A3, 22 Mar 45.

[14] Bomb, Chemical, 100-lb, M47A1, Modification of, to Bomb, Chemical, 100-lb, M47A2, 23 Oct 42. OCM 19111. (2) CWTC Item 803, Classification of 100-lb Incendiary Bombs, 3 Sep 43.

BURNING PHOSPHORUS FROM A 100-POUND INCENDIARY BOMB *on an enemy airfield, Rabaul, New Britain. Aircraft are Japanese Betty-type bombers.*

East Prussia, in October 1943, Flying Fortresses dropped more than thirteen thousand 100-pound incendiaries mixed with high explosives, almost completely destroying the works. That same month the ball-bearing plants at Schweinfurt suffered critical damage from M47 incendiaries and HE. Later in the war and on the other side of the world the XXI Bomber Command frequently employed mixtures of M47's and 6-pound M69 incendiaries in fire raids on Japan. The U.S. Strategic Bombing Survey estimated that an M47 100-pounder was twelve times as effective as a 500-pound general purpose bomb against targets classified as readily inflammable, and one and one half times as effective against targets classified as fire resistant. The M47 napalm filled bomb, uneven as its development had been, proved to be one of the most valuable American bombs of the war.[15]

Germany and Japan had no incendiaries comparable to the American

[15] Crawford, Cook, and Whiting, Statistics, "Procurement." p. 21. (2) *The Chemical Warfare Service in World War II*, pp. 71, 74. (3) Wesley Frank Craven and James Lea Cate, eds, "The Army Air Forces in World War II," vol. II, *Europe: Torch to Pointblank* (Chicago: University of Chicago Press, 1949), pp. 697, 703–704. (4) Wesley Frank Craven and James Lea Cate, eds, "The Army Air Forces in World War II," vol. V, *The Pacific: Matterhorn to Nagasaki* (Chicago: University of Chicago Press, 1953), pp. 614–44. (5) Green, Thomson, and Roots, *Planning Munitions for War*, p. 472.

M47. The closest in weight were 50-kilogram bombs, but these carried explosives in addition to the incendiary filling. In the German bomb the incendiary effect came from thirty pounds of benzene thickened with rubber, with bits of phosphorus scattered through the mixture for ignition. The nose held twenty pounds of TNT, enough to cause a respectable explosion. The German Air Force did not employ this bomb to any great extent, generally relying on other types and sizes.[16] The Japanese missile contained thirty-five pounds of a solution of phosphorus and carbon disulfide, in which were suspended phosphorus-impregnated rubber cylinders an inch long and an inch in diameter. A charge of picric acid in the nose of the bomb caused casualties and could also be set for air bursts which scattered rubber incendiary pellets up to 150 feet. The 50-kg. bomb was generally employed by the Japanese.[17]

Four-Pound Magnesium Bombs

Surprising as it may seem, the first great incendiary raids of World War II were not carried out with large bombs, but with small missiles weighing only a few pounds. In September 1940 the Germans showered London with 1-kg. magnesium alloy bombs, starting innumerable fires, damaging considerable property, and injuring many people. Any doubt concerning the effectiveness of small incendiaries was gone forever. A few months later the Joint Aircraft Committee, established to allocate American materiel between the United States and Great Britain, recommended that the Ordnance Department produce a 4-pound magnesium bomb suitable for the Army, the Navy, and the British. Ordnance thereupon modified the British Mark II/A 4-pound incendiary and standardized it as the American AN-M50 (A standing for Army, N for Navy).[18]

During the preliminary work it became apparent that the old demarcation between the CWS and Ordnance Department which gave the former responsibility for the filling and the latter jurisidiction over the casing would not be an efficient way of manufacturing magnesium bombs. One

[16] German Chemical Warfare Materiel, p. II-D-5.

[17] (1) Japanese Chemical Warfare. (2) Col. George J. B. Fisher, *Incendiary Warfare* (New York: McGraw-Hill, 1946), p. 49.

[18] (1) Memo for the Secretary, Ordnance Technical Committee, 1 Apr 41, sub: Bombs. Standardization by Army, Navy, British Purchasing Committee. Cited as ref a, CWTC Item 1220, Obsoletion of 40-lb Steel Case Type Incendiary Bombs and Clusters for Same, 11 Jan 45. (2) Bomb, Incendiary, 4-lb, and Bomb, Incendiary, 40-lb, Classified as Standard and Designated Bomb, Incendiary, 4-lb, AN-M50, and Bomb, Incendiary, 40-lb, AN-M51, 19 May 41. OCM 16816. (3) Bombs, Incendiary, 4-lb, AN-M50-X, 4-lb, AN-M50, and 40-lb, AN-M51, Clearance for Procurement and Classification as Standard, 22 Jul 41. OCM 17028.

organization should have charge of the entire operation, planners agreed. Ordnance, busy with other munitions and not enthusiastic about incendiaries, dropped out, leaving the CWS in full charge of the AN–M50 and related bombs.[19]

Initial investigations at Edgewood improved the fuze, found substitutes for critical materials (such as a metal plug for a cork plug in the vent), and modified the filling. The completed bomb, AN–M50A1 (A1 signifying the first alteration in the standard munition), was approximately twenty-two inches long, hexagonal in cross section, and about three inches thick. The cast magnesium body held a thermite-type mixture known as therm-8, or thermate. The filling would burn for 1 to 2 minutes, the case for 6 to 7 minutes longer.[20]

Factories began to turn out magnesium bombs in the spring of 1942, slowly at first but soon in tremendous quantities. Most of the bombs went to Great Britain on lend-lease and were dropped in air raids over Europe. The early 4-pound bomb had flaws, as might be expected in a new munition. Fuzes sometimes broke when the bombs struck, first fire mixtures failed to heat fillings to the ignition point, and metal plugs stuck in vents, causing heated air to build up pressure and blow the bombs apart. Furthermore, the British dropped the bombs from higher altitude than the CWS had designed them for, and many of the bombs broke on impact.[21]

Engineers at CWS strengthened the fuze to withstand harder impacts, replaced metal vent plugs with cork, and developed a better first fire mixture. The improved bomb, AN–M50A2, slightly lighter and thinner than its predecessor, functioned well. As fast as the new munitions came from plants they were shipped to Europe and used. The earlier model remained in reserve until 1944 when it was discarded.[22]

[19] (1) Green, Thomson, and Roots, *Planning Munitions for War*, pp. 259, 452. (2) Ltr, C Ord to C CWS, 10 Jul 41, sub: Procurement of Incendiary Bombs, with inds. CWS 471.6/241–280. (3) Notes of conference in office of General Moore at 11 p.m. on 15 July, 1941, by Lt Col J. T. Lewis, Asst SGS, sub: Incendiary Bombs. CWS 471.6/241–280. (4) Brophy and Fisher, *Organizing for War*, ch. II. (5) WD GO 10, Sep 41. (6) WD GO 13, 24 Nov 41.

[20] (1) Therm-8 was a mixture of 80 percent thermite and 20 percent of the Ordnance Department's M8 flare mixture. (2) L. Wilson Greene, "Prewar Incendiary Bomb Development," pp. 25–30. (3) TM 9–1980, 3 Jun 42. (4) TM 3–330, 23 Mar 42.

[21] (1) Ltr, CG SOS ETO to Chm CWTC, 13 Apr 43, sub: 4-lb Incendiary Bomb, AN–M50A1. CWS 471.6/68. (2) Report of Activities of the Technical Division, p. 89.

[22] (1) Capt J. E. Gilbert, Development of 4-lb Incendiary Bomb, AN–M50A2. TDMR 1224, 4 Mar 46. (2) Baum, History of Research and Development of the CWS in WW II, pp. 37–46. (3) S. J. Magram, A Survey of Starters for Burning-Type Munitions. TDMR 655, 24 May 43. (4) Lt J. E. Gilbert, Fillings for Magnesium Incendiary Bombs, AN–M52. TDMR 437, Sep 42. (5) CWTC Item 807, Standardization of Bomb, Incendiary, 4-lb, M50A2, 3 Sep 43. (6) CWTC Item 1017, Obsoletion of Bomb, Incendiary, 4-lb, AN–M50A1, 5 May 44.

Aircraft dropped more 4-pound magnesium bombs than all other incendiary bombs put together. Almost thirty million fell on Europe, and almost ten million on Japan, causing damage that ran into astronomical figures.

Four-Pound Steel-Cased Bombs

The chief obstacle blocking American production of magnesium bombs in 1941 was the scarcity of magnesium. Since the metal had little commercial use before World War II, America did not have a large magnesium industry. During the emergency period firms sent most of the metal to aircraft plants, leaving little available for other purposes. Despite the fact that industry expanded its facilities as rapidly as possible, for a time there was simply not enough of the metal for the armed forces.

The Ordnance Department was aware of these facts when it began development of 4-pound magnesium bombs. It planned a substitute bomb having the same dimensions and incendiary filling as the M50, but with a steel case in place of magnesium. It sent the plans and models of the substitute bomb, called the M54, to the CWS when that service took over responsibility for incendiaries, and the bomb was completed by the technical staff at Edgewood. [23]

The CWS let out contracts, through its procurement districts, for enough metal parts and thermate filling to fabricate twenty million M54 bombs. Contracts were signed in November 1941, and so effectively did industry co-operate that the first missiles were ready for testing at Aberdeen Proving Ground in December, several months before the magnesium bombs came from production lines. Each month millions of bombs were fabricated, filled, and stored in CWS depots to await the call of the Air Forces.

Not all of the bombs, however, remained in storage. On 24 February 1942, the Eastern Chemical Warfare Depot at Edgewood Arsenal received orders to ship forty-eight 500-pound clusters of AN–M54 bombs to Benicia Arsenal, California, for reissue to Lt. Col. James H. Doolittle. The men who filled the order and handled the clusters had no idea of their ultimate destination. Shortly after noon on April 18 a B–25 bomber commanded by Doolittle roared over Tokyo and unloaded some of these

[23] (1) Bomb, Incendiary, 4-lb, T1 Classified as Substitute Standard for Bomb, Incendiary, 4-lb, AN–M50, Designated Bomb, Incendiary, 4-lb, AN–M54, 28 Jul 41. OCM 17052. (2) CWTC Item 412, Approval of Development Project for Small (1 to 2 lb) Incendiary Bomb, and Military Characteristics, 14 Oct 41.

B-25 BOMBER LOADED WITH 500-POUND CLUSTERS OF M54 BOMBS *leaving the flight deck of USS* Hornet *for the first American airstrike against the Japanese homeland, April 1942.*

clusters on the city. Plane after plane followed, bombing factory areas and military installations, while other aircraft struck at Kobe, Yokohama, and Nagoya.[24]

Doolittle's raid, the first American airstrike against the Japanese homeland, was one of the few times during the war when M54 bombs were used. After increasing supplies of magnesium enabled the CWS to procure large quantities of M50 bombs, the service finally halted production of the substitute bomb altogether. Thirteen million M54 bombs lay in warehouses while millions of M50's passed by on their way to air bases. In 1945 when there was no possible chance of M54 bombs being pressed into service again, the CWS declared the model obsolete.[25]

The fact that the Air Forces almost never employed M54's during the war made the production of steel-cased bombs, in one sense, a loss. On

[24] (1) George W. Scaggs, History of the Eastern Chemical Warfare Depot (formerly Edgewood Depot), p. 99. (2) Wesley Frank Craven and James Lea Cate, eds, "The Army Air Forces in World War II," vol. I, *Plans and Early Operations* (Chicago: University of Chicago Press, 1948), pp. 438–44.

[25] (1) CWTC Item 1220, Obsoletion of 4-lb Steel Case Type Incendiary Bombs and Clusters for Same, 11 Jan 45. (2) CWTC Item 1288, same title, 22 Mar 45.

the other hand, these bombs were a reserve for a possible emergency. The contractors had the tools, men, and experience, moreover, to switch to the production of magnesium bombs when magnesium became available. Under the circumstances the loss was more apparent than real.

Clusters for Four-Pound Bombs

Four-pound magnesium bombs and other small incendiaries were not dropped individually, but in clusters which were held together by devices called adapters.

The Ordnance Department began development of the first American adapter. The CWS inherited the item when it accepted responsibility for incendiary bombs.[26] The device was made up of two end plates, two longitudinal bars, and four steel straps, and it held together thirty-four bombs. The adapter was designated as Model M5, the entire cluster of bombs as the AN-M6.[27] A larger adapter, holding 128 bombs, was developed shortly afterward. This adapter was standardized as the M6, the cluster as the AN-M7.[28]

These clusters, known as the quick-opening type, endangered aircraft. Occasionally they opened so quickly that parts glanced off the tail of the bomber. Parts of the adapter also "drifted" through the air and sometimes struck planes coming along below. To keep the cluster intact until it fell a safe distance the CWS devised delay mechanisms. One device blew open the straps twelve seconds (equivalent to a 2,000 foot drop) after the cluster left the plane. Another device was a metal flap, hinged to the end of the adapter. The air jerked up the flap, pulling wires which opened the cluster twenty-five to fifty feet below the plane. The delay mechanisms worked well, but the CWS did not standardize them because aimable clusters were superseding the quick-opening type.[29]

Aimable clusters were developed to improve the accuracy of high altitude bombing. Quick-opening clusters had been suitable for low or medium

[26] (1) Ltr, C CWS to CG EA, 22 Sep 41, sub: Design of Cluster Adapters for 4-lb Incendiary Bombs. CWS 680.429/390. (2) The Ordnance model, T2, is described in TM 3-330, 23 Mar 42.

[27] (1) CWTC Item 898, Standardization of Incendiary Bombs, 21 Jan 44. (2) TM 9-1980, 3 Jun 42. (3) Seth Q. Kline, Robert E. Patchel, and Charles T. Mitchell, Development of Quick-Opening Cluster Adapters, M4, M5, M6, M7, and M8 for Incendiary Bombs. TDMR 1015, 16 Apr 45.

[28] (1) CWTC Item 898, cited above. (2) TM 9-1980, Nov 44.

[29] (1) Capt Theodore R. Paulson and Charles T. Mitchell, Development of Delay Buckle Release on Cluster Adapters for Small Bombs. TDMR 795, 20 Jan 44. (2) Aaron S. Berlin, Development of 100-lb Cluster Adapter E20 for Low Altitude Bombing. TDMR 889, 13 Sep 44.

altitude bombing raids because the bombs landed within a small area. As the war progressed and planes flew at higher altitudes, bombs from quick-opening clusters scattered widely as they fell, many landing completely outside the target area. Aimable clusters prevented this fault by holding bombs together until they were some distance down, then opening by means of a time fuze and allowing the bombs to fall free.

Aimable cluster M17 consisted of an adapter, M10, and 110 4-pound bombs. The total weight was 490 pounds. The adapter was similar to the quick-opening type, but was streamlined by being enclosed in a cylindrical case, and by attachment of a tail fin and round nose. A time fuze adjustable from six to ninety-three seconds regulated the distance that the cluster fell before opening. The fuze detonated a strand of primacord, enclosed in a long tube running the length of the cluster, and the exploding primacord burst the steel straps binding the cluster. Later, on recommendation of the Joint Aircraft Committee, the CWS modified the adapter so that the cluster could be used on British and Navy aircraft. The modified cluster, designated as Model AN-M17A1, was used throughout the remainder of the war.[30]

Explosive Four-Pound Bombs

In any raid a number of bombs would turn out to be duds, others would land on open ground, and still others would burn out in buildings without setting them afire. Therefore only a fraction of the bombs would start a fire and if firemen were alert they had an excellent chance of extinguishing the bombs or limiting the blaze. While airmen could not avoid wasting bombs they could give those that hit the target an opportunity to start conflagrations if they could keep firemen away.

The British solved this problem by producing magnesium bombs containing a small amount of black powder, and mixing these explosive incendiary bombs with the regular type. When bombs landed, fire fighters were unable to distinguish between explosive and nonexplosive bombs and kept their distance. Explosive bombs themselves had a disadvantage since the blast scattered the incendiary mixture and lessened the chance of

[30] (1) CWTC Item 924, Standardization of Adapter, Aimable Cluster, M10 (500-lb size), 21 Jan 44. (2) Seth Q. Kline, Development of Aimable Cluster E4, 500-lb, for Incendiary Bombs AN-M50. TDMR 724 1 Sep 43. (3) CWTC Item 1019, Standardization of Cluster, Aimable, Incendiary Bomb, AN-M17A1, 5 May 44. (4) TB CW 11, Aimable Cluster, AN-M17A1, 27 Jun 44.

a fire; therefore only a small proportion of explosive bombs were mixed with the regular missiles.

When the Ordnance Department began the development of magnesium incendiaries for the American Army early in the war it adopted the British explosive bomb, changed its designation to AN-M50X (the X for "explosive"), and then passed it on to the CWS along with other bombs. Service engineers changed the design slightly, redesignating it as the AN-M50X-A1. The powder charge was held in a plastic cup in the nose of the bomb, and detonated when heat from the filling reached it.[31]

In 1942 the Germans went a step further and substituted lethal TNT for the relatively harmless but terrifying black powder. Raiders flying over Birmingham, England, in July released explosive incendiary bombs that caused more than five hundred casualties. In retaliation the AAF asked that American 4-pounders be loaded with HE.[32] The CWS designed a bomb identical in size, shape, and weight with the standard magnesium bomb, except that it had a hollow steel nose filled with tetryl, detonated by a delay fuze. This fuze gave the incendiary an opportunity to start a fire before exploding. Then tetryl shattered the steel nose and the lower section of the magnesium case into hundreds of fragments, capable of injuring or killing people within a radius of fifty feet. Two types of explosive bombs were produced, one exploding between 1 and 10 minutes after it struck (type A), the other exploding after a delay of 60 to 70 seconds (type B). The bombs were used in the ratio of 4 of type A to one of type B, since this brought about the most uniform distribution of explosions.[33]

The explosive bomb was based on the current 4-pound magnesium bomb, M50A1, and therefore had flaws that appeared in the standard bomb. When the CWS redesigned the latter in 1943 it incorporated similar changes in the explosive bomb, redesignating it as M50X-A3 and employing it throughout the remainder of the war.[34]

[31] (1) Bomb, Incendiary, 4-lb, and Bomb, Incendiary, 40-lb Classified as Standard and Designated Bomb Incendiary, 4-lb, AN-M50, and Bomb, Incendiary, 40-lb, AN-M51, 19 May 41. OCM 16816. (2) Bombs, Incendiary, 4-lb, AN-M50-X, 4-lb, AN-M50, and 40-lb, AN-M51, Clearance for Procurement and Classification as Standard, 22 Jul 41. OCM 17028. (3) CWTC Item 411, Incendiary Bombs, 14 Oct 41.

[32] Ltr, C CWS to CG CWS EA, 17 Aug 42, sub: Incendiary Bomb with Explosive Charge. AGO 471.6/510.

[33] (1) CWTC Item 670, Standardization of Bomb, Incendiary, 4-lb, M50X-A2. (2) CWTC Item 714, same title, 23 Apr 43. (3) L. M. Prince, Jr., Variable Delay Explosive Incendiary Bomb, AN-M50X-A2. TDMR 585, 27 Mar 43.

[34] Louis G. Willke, Development of Bombs, AN-M50X-A3, Type A, Type B, and Type B Alternate. TDMR 1041, 16 May 45. (2) CWTC Item 838, Standardization of Bomb, Incendiary, 4-lb M50X-A3, 15 Oct 43.

In incendiary clusters for the Air Forces, the CWS packed approximately 20 percent explosive incendiary bombs. Model AN-M6 quick-opening cluster contained 34 bombs, of which 6 were explosive. Quick-opening cluster AN-M7 held 128 4-pounders, including 26 of the explosive type. Aimable cluster M17A1 carried 88 incendiary and 22 explosive.[35]

It is not known how many casualties explosive bombs caused, in all probability a relatively small number. But certainly the presence of explosives kept fire wardens from approaching burning missiles and putting them out, with consequent great property damage.

Large Incendiary Bombs

In the spring of 1942 the CWS received reports that German aircraft were dropping large incendiary bombs filled with crankcase oil. The British, too, were employing large missiles filled with rubber thickened gasoline in their raids over Germany. As a result the CWS decided to develop incendiary bombs much larger than any of the standard American models.[36]

A large bomb could not be obtained by simply filling a casing with thickened gasoline. The missile had to be ballistically stable for accurate bombing, it had to burst at the proper moment, and it had to have a device for setting the filling on fire. Beginning with a design similar to the Ordnance Department's 250-pound general purpose bomb, the CWS constructed a missile holding 95 pounds of thickened fuel and weighing 160 pounds filled. Although the bomb was too large and the black powder-magnesium burster igniter failed to set off the filling, the design served as a steppingstone to a better bomb. This munition, smaller and lighter (135 pounds), with less filling (70 pounds), and a HE-white phosphorus burster igniter, seemed likely to be satisfactory. The project came to an end in April 1943, however, when the Army Air Forces asked instead for a 500-pound munition suitable for precision bombing against large industrial targets.[37]

While the 500-pound bomb was being developed the CWS had been experimenting with a new incendiary filling called pyrotechnic or PT-1

[35] Nellie Anson, Clusters and Adapters for Chemical and Incendiary Bombs. ETF 420-21, 1 Dec 47.

[36] (1) Ltr, C Tech Svc OC CWS to CG Edgewood Arsenal, 4 Jun 42, sub: Chemical Bombs. (2) Ltr, C Tech Svc OC CWS to CG Edgewood Arsenal, 6 July 42, sub: Chemical Bombs. Both in CWS 471/51.

[37] (1) Capt Roman L. Ortynsky, The E-1 and the E-2 250-lb Incendiary Bombs. TDMR 1032, 26 Apr 45. (2) Ltr, CG AAF to C CWS, 3 Apr 43, sub: Large Incendiary Bombs. AAF 471.6. (3) CWTC Item 694, Military Characteristics for 500-lb Scatter Type Incendiary Bomb, 23 Apr 43.

fuel. This was a complex material, having as its main ingredient "goop," a mixture of magnesium particles and asphalt used as an intermediate in the Hansgirg magnesium process. To goop was added gasoline thickened with IM, oxidizing agents, and magnesium scraps from magnesium bomb plants. The PT-1 fuel provided a use for magnesium that otherwise would have been wasted. It also gave the service a filling which, because of its hot, metallic ash, was a better fire starter than ordinary thickened gasoline, particularly against targets that did not ignite easily.[38]

As in the case of gasoline thickening agents, HC smoke mixtures, and other materials, the CWS had to look forward to the possibility that a shortage might develop in PT-1. The supply of goop and IM were both critical. Chemists found that IM might be replaced by synthetic rubber, and goop by a magnesium-aluminum alloy. These substitute mixtures, PT-2 and PT-3, were not employed since sufficient ingredients kept coming to produce ample amounts of ordinary PT-1 fuel.[39]

Four types of 500-pound bombs looked suitable on paper, and to determine which was best the technical staff, with co-operation from the Ordnance Department, set to work on all of them. One had a thick steel casing filled with napalm and carrying a HE-white phosphorus burster igniter. Two others were identical with the above except for the casing, one being of thin steel, the other of magnesium. The fourth bomb was filled with a number of small incendiary units that scattered when the bomb exploded.[40]

The thin steel-cased bomb was eliminated midway in development because of production difficulties, but the other three went through the testing process. The final choice, based on ease of production and bombing results against industrial-type test buildings, was the thick steel-cased missile, designated as AN-M76.[41]

The AN-M76, essentially a modified 500-pound general purpose bomb,

[38] Capt W. A. Franta, Capt Harvie Barnard, and James S. Carson, Development of PT1 Incendiary Gel (pyrogel). TDMR 1283, 2 Mar 48.

[39] (1) Capt E. J. Schantz, Lt Bradley Dewey, Jr., and James S. Carson, PT-2 Incendiary Gels Thickened with Synthetic Rubber. TDMR 962, 22 Jan 45. (2) Capt Bradley Dewey, Jr., and James S. Carson, PT-3 Incendiary Gels Thickened with Synthetic Rubber. TDMR 1180, 21 Feb 46.

[40] (1) Capt Roman L. Ortynsky, The 500-lb Incendiary Bomb, E1. TDMR 1043, 1 May 45. (2) Capt William H. Daiger, Test of the 500-lb. Magnesium Incendiary Bomb, E12. TDMR 1049, 12 May 45. (3) Capt Julius Kovitz, Development of 500-lb Tail Ejection Incendiary Bomb, E16. TDMR 1016, 30 Mar 45.

[41] (1) Capt Roman L. Ortynsky, The AN-M76 (T2-E1) 500-lb Incendiary Bomb. TDMR 1028, 25 Apr 45. (2) CWTC Item 928, Standardization of Bomb, Incendiary, 500-lb, M76, 21 Jan 44.

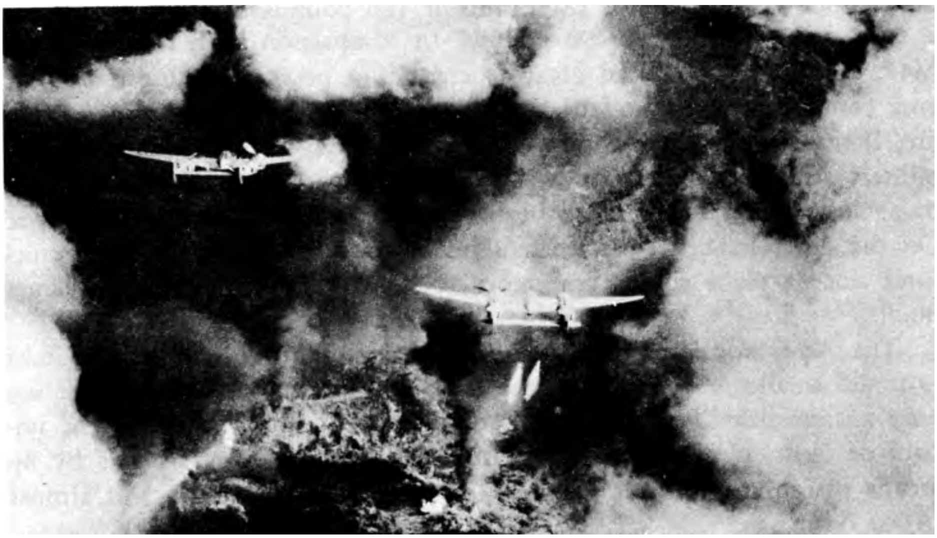
held either 115 pounds of IM filling or 180 pounds of PT-1 filling, for a total weight of 425 or 490 pounds. In comparison with the 100-pound M47, the 500-pounder had greater penetrating power, was more accurate and, containing three to four times more filling, created a more intense fire. It was therefore the choice against strongly constructed industrial and military structures that might withstand the impact of a 100-pound bomb, or against targets that had to be bombed accurately from high altitudes. On the other hand, it was wasteful to drop 500-pounders on light structures since a plane could carry more 100-pound bombs and start a larger number of fires. [42]

The Army Air Forces did not drop nearly as many 500-pound bombs as it did smaller missiles, since the large munitions were intended for use only against heavily roofed structures that could stand up under the impact of light bombs. Still, the number dropped by aircraft was by no means insignificant, more than 39,000 falling on Germany and almost 38,000 on Japan.[43]

The five-hundred pound bomb was the heaviest incendiary standardized by the CWS, but several larger missiles went part way through the development stage. The idea of a 1000-pound incendiary had its origin in the fire bomb, prepared in the field by filling droppable airplane gas tanks with thickened gasoline. Since the Navy already had a 1000-pound practice bomb, Mk 66, the CWS decided that modification of the Navy missile would be the quickest means of producing an incendiary bomb of this size. Engineers loaded the Mk 66, using a range of napalm fillings and a variety of burster igniters, but V-J Day arrived before the work was completed. [44] The Navy's 2000-pound bomb, Mk 67, served in the same manner as a model for a 2000-pound incendiary, and the end of the war also brought an end to this project. [45]

The large bombs of the German Air Force weighed approximately 250 and 550 pounds. They were thin shelled missiles filled with crude oil and were not particularly efficient. Thickened fillings, which probably would have increased the effectiveness of the bombs, were just coming into use when Germany surrendered. Japan's largest incendiary bomb, weighing about 550 pounds, was radically different in design from American or German bombs. It contained more than 700 open-end iron cylinders filled

[42] TB CW 4, Bomb, Incendiary 500-pound M76 (T2-E1), 4 Apr 44.
[43] *Chemical Warfare Service in World War II*, p. 74.
[44] Gaul and Finkelstein, Incendiaries, pp. 585-91.
[45] *Ibid.*, pp. 591-92.



LOCKHEED P-38'S DROPPING FIRE BOMBS *near Ipo Dam, Luzon.*

with thermite. Fuzed to burst 150 to 200 feet above the ground, the bomb scattered the cylinders, which continued to burn for about one minute, over a radius of 500 feet.[46]

Fire Bombs

Somewhere early in the war a pilot dropped his spare gasoline tank on an enemy position, circled back and ignited the gasoline with tracer bullets. Who the first pilot was to employ his fuel tank as a bomb and where the action took place are not matters of record, but the event marked the birth of the fire bomb, as this type of incendiary was called. Jettisonable wing and belly tanks were convenient because they were on hand at almost all airfields and could be employed as bombs without affecting their primary purpose as gasoline containers. The Army Air Forces tried to find a device that would fire the gasoline when the tank smashed into the target, and thus save the pilot from making a dangerous, low altitude pass over the area to ignite the gasoline with tracers. They tried attaching incendiary grenades and small incendiary bombs to tanks, but tests

[46] (1) Japanese Chemical Warfare. (2) German Chemical Warfare Materiel, p. 160. (3) Fisher, *Incendiary Warfare*, p. 49.

showed that these makeshift igniters were not reliable. The AAF then asked the CWS to design an igniter that would function at least 90 percent of the time, and would be so small that it would not change the streamlined shape of the tank.[47]

After considerable work, including the standardization of an igniter that later proved unsatisfactory, engineers devised two fairly reliable devices. One was inserted into the tank through the gasoline cap, the other was fastened to the tail. To make doubly certain that the fire bomb would burn, both types could be attached. Spontaneouly ignitable white phosphorus was the filling for use on land, sodium for targets on water.[48]

Fire bombs were employed on a variety of missions in the theaters from mid-1943 onward. At Tinian, low-flying P-47's dropped wing and belly tanks, generally filled with an oil-gasoline mixture since napalm was still scarce, on beaches as a preliminary to marine landings, and on overgrown areas to burn away foliage concealing enemy installations.[49] On Luzon, fire bombs proved to be "one of the most effective implements of aerial-delivered destruction," in burning off wide areas of vegetation, and in setting fire to enemy held villages.[50] A 165-gallon fire bomb holding approximately 960 pounds of thickened gasoline could burn off vegetation in an oval-shaped area 300 feet long and 100 feet wide. In Europe the XIX Tactical Air Command used fire bombs effectively in attacks on deep shelters because of their effect on ventilating systems, and in strikes against gun positions where intense heat impaired or destroyed enemy artillery.[51]

Fire bombs were made in many sizes, from small tanks holding 30 gallons up to tanks of 300-gallon capacity. In Europe the most popular sizes were 100, 108, and 110 gallons; in the Pacific 150 and 165 gallons. All together, the AAF dropped more than 12,000 fire bombs over Europe, while Army, Navy, and Marine planes in the Pacific employed twice that number against the Japanese.[52]

[47] Gaul and Finkelstein, Incendiaries, pp. 550–83.

[48] (1) Tests of the AN-M52A1 and AN-M52XA1 Bombs, Modified as Igniters (E1 and E1R1) for Droppable Fuel Tanks. TDMR 1172, 9 Nov 45. (2) Development of Fuze Adapters and Bursters for the Igniter, Incendiary Gasoline Tank. TDMR 1089, 13 Aug 45. (3) CWTC Item 1174, Standardization of Igniters, M15 & M16, 11 Jan 45.

[49] Hoffman, *The Seizure of Tinian,* pp. 34–35, 37.

[50] Maj Charles W. Boggs, Jr., "Marine Corps Monographs," *Marine Aviation in the Philippines* (Washington, 1951), p. 92.

[51] *After Action Rpt, Third U.S. Army, 1 Aug 44–9 May 45.* vol. 1, an. 3, p. 2.

[52] *Chemical Warfare Service in World War II,* p. 75.

The Six-Pound Oil Bombs

The incendiary bomb most widely used against Japan was a 6-pounder. The NDRC conceived the idea for the bomb in 1941 after European air raids had proven the effectiveness of small incendiaries. Since magnesium was scarce, the NDRC contracted with the Standard Oil Development Company for a steel-cased bomb filled with thickened gasoline.[53]

The new bomb differed in principle from standard and experimental CWS munitions. Instead of burning where it landed, like the 4-pound magnesium bomb, or bursting and scattering its contents over a wide area, like the 100-pound bomb, the missile acted like a small mortar, ejecting a single blob of filling a distance of several yards. To achieve this, engineers devised a radical design. Inside the bomb at the forward end they put the fuze, followed by a small powder charge to eject and ignite the filling, then the filling of jellied gasoline contained in a cheesecloth sack, and finally, at the base, tail streamers. When the missile came to rest in the attic of a building, for example, the powder blew the filling out of the bomb. The filling hit the underside of the roof, stuck there, and burned.

An innovation in this bomb was the design of the stabilizers. Instead of metal fins the tail consisted of cloth ribbons. These saved weight and space (the ribbons were folded in the base of the bomb and were unfolded by the airstream). Also, because of air resistance, they kept the bomb from dropping too fast and penetrating too deeply. The ideal velocity would be just enough for the bomb to break its way through a roof and come to rest on the rafters.

Designers started off by modeling bombs of different sizes, but after tests, including "raids" against abandoned buildings at Jefferson Proving Ground, demonstrated the superiority of the 6-pound bomb, they concentrated on it. The completed bomb was approximately a foot and a half long, hexagonal in cross section, and about three inches thick. The service standardized it as the M69 in 1942, less than a year after the project began, and started production in November.[54]

Several flaws showed up in proofing carried out with samples from the production line. Cloth tail ribbons could not stand the sudden pull as they snapped outward in mid-air, and they tore loose from bombs.

[53] (1) Noyes, *Chemistry*, pp. 389–96. (2) *Fire Warfare*, pp. 7–31.

[54] (1) CWTC Item 529, Standardization of 6-lb Oil Incendiary Bomb and 500-Pound Cluster Adapter, 4 Aug 42. (2) CWTC Item 570, same title, 29 Sep 42. (3) CWTC Item 621, Redesignation of Bomb, Incendiary, Oil, 6-lb, M56, 24 Nov 42. (4) TM 9–1980, Nov 44.

Fuzes did not always function, and fillings did not always ignite. After these weak points were corrected, more than 90 percent of the bombs caught fire when they landed.[55]

Originally, M69's were dropped in quick-opening clusters, similar to the clusters used for small magnesium bombs. All went well until aimable clusters appeared in 1943. These, since they were streamlined and released from high altitudes, attained considerable velocity by the time they opened. Tail ribbons on the bombs unfolded with a terrific jerk, tearing the cloth or snapping ribbons completely off the missiles. Apparently all that had to be done was to find sturdier cloth and a stronger method of attachment. Actually engineers had considerable difficulty finding cloth strong enough to stand the strain, yet light enough not to unbalance falling bombs. Then, after finding suitable cloth, the CWS was not able to procure all it needed. The problem continued throughout the war, forcing the CWS to make several modifications in the ribbon retaining mechanism and in the ribbons themselves.

Supplies of M69 bombs became available in 1943, at a time when the AAF was giving thought to the strategic bombing of Japan. Many believed that incendiaries would be highly effective against the wooden structures in Japanese cities. The Air Forces already knew something of what British and American incendiaries could do in Europe. Could that experience be measured and tested for use against Japan? New incendiary munitions had been under development. What was the best incendiary for the new mission?

These questions were answered in bombing "raids" against industrial-type buildings at Edgewood, against a simulated Japanese village constructed by the AAF at Eglin Field, and in the successive razing and rebuilding of a composite German-Japanese village at Dugway. Among the points that had to be determined was the degree of penetration of bombs, and the time-temperature factor for igniting the typical Japanese target.

These large-scale, costly field tests demonstrated the merits and defects of different bombs, and indicated that the M69 would be effective. The missile wobbled and therefore was not always accurate, but its inaccuracy turned out to be of little moment in the low altitude, large area bombing later carried out over Japan.

The great air campaign against the Japanese islands began in November

[55] (1) Report of Activities of the Technical Division, p. 98. (2) Gaul and Finkelstein, Incendiaries, pp. 402–06. (3) Capt Roman L. Ortynsky, Tests of M69 Bombs at Huntsville Arsenal, February 4–9, 1943. TDMR 576, 17 Feb 43.

1944, taking the form of high altitude precision bombing with HE bombs. At first incendiaries were dropped only in inconsequential numbers. Then on 25 Februrary 1945 the XXI Bomber Command changed its bombs and hit Tokyo with more than 400 tons of M69's. Photos from reconnaissance flights showed that approximately a square mile of the urban area had been destroyed or damaged. This marked the turning point in bombing tactics. Maj. Gen. Curtis LeMay adopted the policy of low level area bombing with incendiaries. On the evening of March 9, more than 300 superforts swarmed over Tokyo, dropping about two thousand tons of incendiaries, mostly clusters of M69's. Photographs indicated that almost 16 square miles of the city had been burned out. Tokyo police records, examined after the war, showed that more than one-quarter of a million buildings were destroyed—about one-fourth of the total in Tokyo. It was the most devastating fire raid of the war up to that time. Before representatives of Japan appeared on board the USS *Missouri,* AAF bombers had dropped more than one hundred thousand tons of incendiaries on Japan, most of them M69's. The tremendous destruction wrought in the Orient showed how accurate had been the foresight of those who planned this bomb four years earlier.[56]

Incendiary Oddities

The incendiary bombs just discussed include those important in operations; yet they represent only a minor proportion of the aerial incendiaries that the CWS worked on during the war. By itself or in co-operation with the NDRC, under its own initiative or upon request from other branches of the armed forces, the CWS undertook the development of many other incendiary bombs. Some went part way through the development cycle, others proceeded all the way to standardization.

An example of a munition that was standardized but never employed is the incendiary leaf, developed in 1941–42 by the CWS and the Celanese Corporation of America. It was intended for dry grain fields, forests, thatched roofs, and other targets that would burn easily. As with the 4-pound magnesium bomb, the idea came from the British. Leaves were made in the form of disks, eight inches in diameter, one-fourth of an inch thick, and composed of pyroxylin. One type had pellets of white phosphorus attached to it, embedded in a putty-like material. When containers

[56] (1) Craven and Cate, *The Pacific: Matterhorn to Nagasaki,* chs. 18, 20, 21, 23. (2) *Chemical Warfare Service in World War II,* p. 74.

of leaves were dropped, they opened in mid-air and the leaves spun to the ground. The sun dried and cracked the covering material, permitting air to ignite the phosphorus and this, in turn, the leaf. Another type was coated with a friction sensitive chemical. These were stored and dropped in containers filled with a desensitizing fluid. The containers opened, the leaves whirled away, and the liquid evaporated. On striking an object of any kind, the leaf burst into flame. The CWS standardized these incendiaries, but when intelligence reports indicated that leaves dropped by the British on Germany had caused little, if any, damage, the service abandoned the munition.[57]

One example of an incendiary that seemed useful in the planning stage, but proved unnecessary after it was developed and tested, was a device to ignite oil slicks on water. In September 1942 the Navy Bureau of Ordnance asked the CWS to devise such a munition. The service modified existing incendiary bombs for the job, and also tried containers filled with calcium carbide (carbide reacts with water, producing acetylene which catches fire from the heat of reaction).

The NDRC took a different approach and designed the city slicker. This was a container filled with small cardboard cartons, each carton holding an incendiary mixture, chiefly magnesium dust and a bag of calcium carbide. Dropped from a bomber, the container opened and spilled the cartons into the air. When they landed water entered through holes, was heated by reaction of the carbide, and then acted on the incendiary mixture.

Tests finally showed that the standard, 100-pound incendiary bomb filled with thickened gasoline and fitted with a sodium burster ignited oil slicks with fair regularity. An additional advantage of using this bomb was that industry would not have to produce oil slick igniters and the armed forces would have one less munition to clutter up supply channels. Engineers therefore stopped work on oil slick igniters and turned to other projects.[58]

While the incendiary leaf and city slicker were unusual, they were no match in this respect for the bat incendiary. This bomb was conceived on the day the Japanese bombed Pearl Harbor. Lytle S. Adams, a dental surgeon from Pennsylvania, was returning from a visit to Carlsbad

[57] (1) James S. Carson, WP Incendiary Bomb M2 (Leaf). TDMR 482, 17 Dec 42. (2) Red Phosphorus Incendiary Bomb M1 (Leaf). TDMR 484, 23 Dec 42. (3) CWTC Item 354, Bomb, Incendiary, Leaf, 22 Jul 41. (4) CWTC Item 598, Withdrawal of Military Requirement for Incendiary Leaves, 24 Nov 42.

[58] Capt Roman L. Ortynsky, Ignition of Oil Slicks on Water. TDMR 814, 4 Mar 44.

Caverns when news of the attack came over his car radio. The thought flashed through his mind that the millions of bats in American caves might be fitted with incendiary bombs and dropped on Japan. He drove back to Carlsbad, captured some bats for tests, ransacked libraries for data on the subject, and in January sent his proposal to the White House. President Roosevelt OK'd it, and the project was on.

Adams and his search teams drove hundreds of thousands of miles, traveling day and night, to explore bat caves. In their yearlong survey they found America's largest colony, estimated at between 20 and 30 million bats, in Ney Cave, Texas. In 1943 the CWS and NDRC began to design an incendiary weighing less than an ounce for attachment to bats. The finished product was an oblong, nitrocellulose case filled with thickened kerosene and carrying a delayed-action igniter. Two sizes were made, the larger capable of burning for six minutes, the smaller for four. A bomb was attached to the loose skin on the bat's chest by a surgical clip and a piece of string. When released from a container that opened automatically in mid-air, bats were supposed to fly into hiding in dwelling and other structures, gnaw through the string, and leave the bombs behind.

All sorts of complications arose to slow the project. Bats were cooled to force them to hibernate. They could then be handled and transported and not have to be fed (a bat can eat many times its own weight of insects each day). But artificial cooling was tricky business, and in early attempts the bats did not wake up. After this problem was solved and bats were taken aloft for test flights, many failed to co-operate and either flew away or else dropped to earth like stones. Some bats got loose from a careless handler and set fire to a hangar and to a general's automobile.

The Army gave up the project to the Navy, which passed it along to the Marine Corps. All this experimentation took time, and in 1944 when the Chief of Naval Operations found that bats would not be ready for combat until mid-1945 he canceled the project. So ended the most extraordinary incendiary bomb of the war, leaving those who were acquainted with it to wonder what would have happened if bomber bats had been released over Japan.[59]

Less weird than the bat incendiary was the butane bomb. It was well known that mixtures of hydrocarbon vapors and air would explode under

[59] (1) Robert Sherrod, *History of Marine Corps Aviation in World War II* (Washington: Combat Forces Press, 1952), p. 129. (2) Charles E. Mohr, "Texas Bat Caves Served in Three Wars," *National Speleological Society Bulletin* no. 10 (April 1948), pp. 89–93. (3) Capt Wiley W. Carr, Live Carriers for Small Incendiaries. ETF 180-27, 8 Jun 43.

certain conditions if touched by a flame. A number of serious industrial accidents had been traced to the presence of such explosive mixtures. At New London, Tex., 18 March 1937, almost 300 children were killed in a school when natural gas leaked into the air and exploded.

After war broke out the CWS considered the possibility of using butane and similar hydrocarbons as incendiary agents or explosives. Theoretically, bombs filled with butane would burst and the gas would escape into the air, forming an explosive mixture. Finally a board of officers studied the technical difficulties in the way of using butane in bombs. After it concluded that butane offered "no advantage over current standard explosive and incendiary agents," the matter seemed to be settled. Nevertheless in July 1944 Lt. Gen. Brehon B. Somervell ordered the CWS to investigate the usefulness of explosive hydrocarbon mixtures as fillings for bombs and other munitions. A few months later the AAF added its voice to Somervell's. Although the CWS was aware that butane munitions were impractical, it had no choice but to assign men to the project. Engineers detonated butane "bombs" statically at Edgewood, and then dropped actual bombs on Japanese-type fortifications at Dugway. These tests convinced the Army and AAF that while mixtures of butane and air would explode quite handily under laboratory conditions, it was impossible to get a vigorous explosion in the field because of such uncontrollable factors as wind velocity, air temperature, ignition time, point of impact of the bomb, and type of target. The CWS dropped the project without any further objecttion from the Army or AAF.[60]

An incendiary of an entirely different kind from those that have been mentioned was the Weary Willie. By the end of 1944 the AAF had a number of worn-out aircraft that could no longer be used safely in combat. Someone came up with the idea that these planes might be loaded with explosives or incendiaries and flown by remote control over important targets in enemy territory. The Army handed the CWS the problem of determining the most effective incendiary cargo for these Weary Willies or remote controlled bombs.

At Edgewood, engineers tried to figure out the best payload by stacking different kinds and sizes of incendiary bombs as they would be piled inside the planes, and igniting them. This method of testing did not work out very well because engineers could not duplicate the conditions under which bombs would be used. The service laid plans for simulated

[60] Capt R. E. Bolgiano, Development of an Inflammable Gas Bomb. TDMR 1136, 24 Sep 45.

bombing raids, but before they could be carried out the AAF dropped the idea of employing Weary Willies.[61]

In addition to the aerial incendiaries discussed above, the CWS worked on 3-pound, 6-pound, 25-pound, 30-pound, and 40-pound bombs; a 2-pound bomb with a plastic case; the 2-pound magnesium bomb, AN–M52, abandoned because of poor ballistic properties; and the 10-pound M74, produced too late in the war for wide use. The reason that so many models were designed and then discarded somewhere along the development line is that incendiary bombs, as a means of mass destruction, were new in World War II and the necessary characteristics were not well defined. The CWS, Ordnance Department, and AAF learned what physical and incendiary properties were required in a satisfactory bomb only as large-scale, expensive tests were completed at proving grounds, and as surveys of American bombing raids became available. Even when items were unsatisfactory the effort that went into them was not entirely wasted. From failures engineers and chemists got information that could be applied to the development of successful munitions.

Incendiary Grenades

Second only to incendiary bombs in terms of wartime production were incendiary grenades. The CWS between 1942 and 1944 procured more than eight million which were employed wherever American troops saw action.[62]

The standard grenade, AN–M14, consisted of a round tin can, of the same type used for smoke grenades, loaded with a thermite mixture. It was born in late 1940 when the Infantry and Engineers asked for a munition that could destroy enemy matériel or American equipment on the verge of capture. Ordnance engineers designed the grenade body while CWS chemists developed the filling.[63]

What the users wanted was a munition that could burn through crankcases, cylinder heads, and transmission cases; fuse breech mechanisms beyond repair; ruin the rifling of large cannon; weaken bridge girders and steel rails; and burn through armor plate on tanks. But it was not pos-

[61] (1) CWTC Item 1270, Military Requirement and Military Characteristics for Incendiary for Remote Controlled Bombs, 22 Mar 45. (2) CWTC Item 1439, Cancellation of Projects in CWS Project Program for 1945, 2 Aug 45.

[62] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[63] Capt J. W. Gilbert, Development of Grenade, Incendiary, AN–M14. TDMR 1114, 22 Aug 45.

sible to design a grenade-size incendiary capable of doing all of these things because the small quantity of filling could not provide sufficient heat. What the Army got was a grenade containing about one and one-half pounds of a thermite-type mixture, able to fuse the breech of a 37-mm. gun, ruin the bore of 75-mm. guns and larger, and burn through quarter-inch steel plate.

Production began in 1942. By 1943 there were so many AN-M14's on hand, and troops were using them so slowly, that the CWS stopped production and made no more for the remainder of the war.

In the field, rangers carried these grenades on raids into enemy territory. Infantrymen used them on trip wires to catch prowling Japanese at night, to destroy disabled American tanks, to ignite gasoline poured into enemy caves and fortified positions, and to signal after dark. While the AN-M14 was one of the grenades least employed, it served a useful purpose in special situations. [64]

The CWS investigated two other kinds of incendiary grenades, a bursting type and a frangible type. The bursting type, containing a small explosive charge to scatter the burning incendiary mixture, did not go beyond the experimental stage. The frangible type, however, got more attention. These grenades, made from glass bottles filled with gasoline and carrying cloth wicks in the necks, came out of the Spanish Civil War. In action the soldier poured a bit of gasoline on the wick, touched it with a match, and threw the bottle. Upon impact the bottle burst and the gasoline went up in flames.

Despite their crudeness, Molotov Cocktails, as they were called, could put tanks and mechanized vehicles out of action. In addition they could be produced quickly and easily. These factors led the CWS to investigate frangible grenades in 1941.

Technicians first tried to improve the old Molotov Cocktail by making it self-igniting. To do this they added alcohol to the gasoline, and attached a tube of chromic anhydride to the bottle. When the bottle broke the gasoline was ignited by the reaction between the alcohol and anhydride. While this munition, standardized as frangible grenade (GA) M1, worked satisfactorily, it was dangerous to produce, store, and ship. A bottle broken accidentally could start a fire that might destroy a plant,

[64] (1) "American Forces in Action Series," *Small Unit Actions* (Washington, 1946), pp. 31–34. (2) H. M. Cole, *The Lorraine Campaign,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1950), p. 386. (3) Maj John N. Rentz, "Marine Corps Monographs," *Marines in the Central Solomons* (Washington, 1952), p. 87. (4) "Klieg Lights in the Jungle," *Chemical Warfare Bulletin* 30 (Jun–Jul 44), p. 32.

warehouse, or ship. No grenades of this type were ever stored or issued to troops and in 1943 the service discarded them.[65]

Next, engineers tried using ordinary railroad fusees as igniters, taping them to the grenades. In operation the soldier pulled a wire leading from the fusee to start it burning and then tossed the bottle. Although this type of igniter seemed safe, it would not flare up when wet and therefore had to be discarded. Finally engineers came up with a small igniter that fired a .38 caliber blank cartridge into the gasoline at the instant the bottle broke. This device remained standard on all frangible grenades.[66]

For grenade fillings the CWS had a range of flammable materials. An early mixture, copied from the British, contained carbon disulfide, white phosphorus, and rubber. This filling was spontaneously flammable and therefore hazardous in filling plants and storage depots. Within a few months the service discarded it and adopted gasoline thickened with napalm (NP) and isobutyl methacrylate (IM).[67]

The CWS turned out more than a half million frangible grenades mostly with IM fillings. They were hardly worth the trouble involved. When it came to dealing with enemy armored forces, American troops preferred antitank guns, bazookas, cannon, and other weapons.

The Japanese had a "potato masher" or stick-type grenade consisting of a cylindrical body attached to a wooden handle. The filling was composed of white phosphorus, carbon disulfide, and pellets of rubber. Germany had two incendiary grenades. The frangible glass type contained gasoline. Two matches fastened to the bottle served as igniters. The metallic grenade, used to destroy equipment that might be captured, was a 1-kilogram incendiary bomb with the tail removed, and the bomb fuze replaced by a pull-igniter. The Germans and Japanese both found incendiary grenades useful items of special equipment.[68]

Incendiary Shells

The CWS did its initial work on incendiary shells for the Navy, which wanted munitions that submarines, surface raiders, and regular naval ves-

[65] (1) CWTC Item 562, Standardization of Incendiary Filled Frangible Grenades, 29 Sep 42. (2) CWTC Item 609, same title, 24 Nov 42. (3) CWTC Item 746, Obsoletion of Grenade, Frangible, M1, 11 Jun 43.

[66] (1) CWTC Item 692, Obsoletion of Grenade, Frangible, M1, 23 Apr 43. (2) CWTC Item 746. (3) CWTC Item 737, Standardization of Igniter, Frangible Grenade, M3, 11 Jun 43.

[67] (1) CWTC Item 692. (2) CWTC Item 746. (3) CWTC Item 902, Reclassification of Incendiary Fillings for Grenade, Frangible, M1, 21 Jan 44.

[68] (1) Japanese Chemical Warfare. (2) German Chemical Warfare Materiel, pp. I–J–7, I–J–9.

sels could use to burn junks, sampans, warehouses, barracks, and supply dumps. In early experiments CWS engineers tested base ejection shells filled with thickened gasoline and white phosphorus, but these missiles generally atomized the filling instead of ejecting it whole, and the men discarded the idea.

They then turned to exploding-type shells filled with small incendiary canisters. Steel and magnesium canisters of different sizes containing a number of incendiary mixtures were tried. The experiments had to take into account the shell velocity, type of fuze, and construction. The large number of variables that had to be investigated slowed the work and it was many months before the service narrowed its choice to a 5-inch shell containing four cylindrical canisters, each filled with a special thermite mixture. The end of hostilities terminated this project.[69]

The AAF presented the service with a similar problem in 1944 when it asked for incendiary shells that 75-mm. aircraft cannon could fire at cargo vessels and fuel dumps. The CWS munitions experts started with base ejection shells containing small magnesium canisters. It was no easy matter to find an incendiary filling suitable for the canisters. Nor was it easy to design canisters that could be blown from a 75-mm. shell, ignite, and set fire to the target. To complicate matters still more the capacity of 75-mm. shells was so small that the shells were not effective unless they landed in a highly flammable area and then functioned perfectly. All these obstacles blocked progress during 1944. Finally in 1945 it became evident that the project was impractical, and it was canceled.[70]

Like the Navy and AAF, the CWS itself had thought of using incendiary shells. White phosphorus mortar shells, normally employed for laying down smoke or causing casualties, could start fires under favorable conditions. For example, dry hay or leaves might be ignited. But WP would not ordinarily set fire to wooden structures.

In 1943 the service set out to develop base-ejection incendiary shells, then canceled the project in 1944 when a survey of the theaters of operation showed that only the CBI had use for such a munition. Later that year the ETO changed its mind, and in January 1945 the service resumed the project. By V-J Day development had reached the point where the

[69] (1) Gaul and Finkelstein, Incendiaries, pp. 647–65. (2) Capt J. H. Hayes and Capt E. R. Marshall, 5-Inch Navy Shell. TDMR 1112, 26 Sep 45.

[70] (1) Capt Julius Kovitz, Development of 75-mm. Base Ejection Incendiary Shell, T-34. TDMR 1190, 13 Dec 45. (2) CWTC Item 1439, Cancellation of Projects in CWS Project Program for 1945, 2 Aug 45.

Army authorized limited procurement of 4.2-inch mortar incendiary shells for field tests.[71]

American forces did not press for incendiary shells because they were useful only in special situations. This occasional usefulness had to be weighed against the inconvenience of another item in supply channels. Furthermore, white phosphorus ammunition served the purpose of incendiary ammunition where the target was easy to ignite.

If we can judge by the variety of incendiary shells in the German and Japanese armies, both these nations placed a higher value on them. The Japanese army had incendiary 75-mm. artillery and 90-mm. mortar shells filled with white phosphorus, carbon disulfide, and rubber pellets. This mixture was the same as the one used in Japanese incendiary bombs. The Navy employed a 12-cm. antiaircraft shell loaded with steel pellets filled with white phosphorus. When this shell exploded the pellets streaked through the air and caught fire.[72]

Among German incendiary munitions were 50-mm., 100-mm., and 105-mm. shells containing high explosive and thermite. They were felt to be particularly effective against tanks. An 88-mm. antiaircraft shell was reminiscent of the Japanese AA shell in containing a number of small incendiary slugs. It was more spectacular as a fireworks display than as a munition for shooting down planes.[73]

Incendiary Rockets

In addition to incendiary bombs, grenades, and shells, the CWS worked with incendiary rockets. Rocket research, to determine if the munitions would be suitable for toxic fillings, was first undertaken for the service by the NDRC in 1941. Incendiary fillings became the subject of CWS experimentation two years later, with the Ordnance Department and Navy co-operating in the design of rocket bodies and mortars.

In 1943 the CWS began to develop a 2.36-inch incendiary rocket for the bazooka. Chemists filled shells with various thermite and PT mixtures and tested them. The missiles were not stable ballistically, and the fuel would not always ignite upon impact. While these problems might eventually have been solved, there was another obstacle that proved insurmountable. The rocket cavity held so little filling that it was practically

[71] (1) Gaul and Finkelstein, Incendiaries, pp. 665–75. (2) Lt Oren E. Ross, 4.2-Inch Chemical Mortar Shell, Incendiary, E66R3. TDMR 1218, 5 Mar 46.

[72] (1) Tactical and Technical Trends, no. 22, 8 Apr 43, p. 17. (2) Japanese Chemical Warfare.

[73] German Chemical Warfare Materiel, p. I–H.

useless in starting fires. The CWS gave up, and thereafter worked with larger missiles.[74]

A much more suitable rocket, from the viewpoint of quantity of filling, was an 8-inch missile that the service devised by adding a rocket motor to the tail of the Ordnance AN-M30 30-pound bomb. Loaded with PT fuel, this rocket could range up to 600 yards. When it landed a burster igniter broke open the casing and scattered burning fuel over a radius of sixty yards.[75]

In similar fashion the CWS and Ordnance Department Rocket Research Division evolved an incendiary rocket from the AN-M57 250-pound general purpose bomb. With three rocket motors attached to the base, the bomb would fly almost half a mile. Containing eighty pounds of PT fuel, this was the largest experimental rocket worked on by the service.[76]

The development of incendiary rockets for the Army proceeded slowly until the autumn of 1944, because none of the theaters or branches of the armed services set up a military requirement for the munition. Then a joint Army-Navy testing and experimental board asked for one hundred 7.2-inch incendiary rockets for trial. This became a joint project of the Ordnance Department and CWS, with the latter filling the rocket with incendiary fuel and fitting it for bursting and ignition. The rocket head held about twenty pounds of PT fuel, a quantity shown by test to be adequate for starting fires. This rocket was never standardized, but the CWS would have considered it satisfactory for use as a standard munition if the need for such a rocket had arisen.[77]

The Navy was more interested than the Army in incendiary rockets. In 1943 it considered the possibility of firing 3.5-inch incendiary rockets from LCT's during amphibious operations. Engineers at CWS carried out experiments that indicated rockets of this size, like the 2.36-inch bazooka rocket, could not hold sufficient incendiary filling. The Navy turned to the 4.5-inch rocket, with the thought that it might be used to burn light structures, such as nipa shacks, in the Pacific. Rockets of this size filled with PT fuel and fitted with an HE burster and WP igniter satisfied the requirements set up by the Navy. The end of the war cut off the development of 4.5-inch rockets at the service test stage.[78]

[74] J. J. Jungbauer, Development of the 2.36-inch Chemical Rockets. TDMR 850, 24 Jun 44.

[75] R. E. Bolgiano, Development of 8-in. Incendiary Rocket E2. TDMR 893, 25 Sep 44.

[76] R. L. Ortynsky, Development of 11-in. Incendiary Rocket, E33. TDMR 1101, 21 Aug 45.

[77] R. E. Bolgiano, Development of 7.2-in. Incendiary Rocket Head E27. TDMR 1146, 16 Oct 45.

[78] (1) R. E. Bolgiano, Tests of the 3.5-inch Incendiary Rocket Mk 11. TDMR 1184, 28 Nov. 45. (2) R. E. Bolgiano, Test of the 4.5-inch Incendiary Rocket Mk 9. TDMR 1161, 2 Nov 45.

The development of incendiary rockets proceeded slowly because the Army did not ask for them and the Navy was only mildly interested. Without a definite military requirement, the CWS was not justified in diverting men and funds from crucial projects. The work done was exploratory in nature, and served to give engineers experience that would have been useful if theaters of operations had suddenly requested incendiary rockets to place beside HE rockets.

In World War II the Chemical Warfare Service's greatest stride was in the field of incendiaries. During the period from 1941 to 1945, all its standard bombs and grenades, experimental shells and rockets, sprang forth. The service procured more incendiary bombs than any other single item, and it spent more money and employed more manpower on incendiaries than on an any other item of supply.

CHAPTER IX

Smoke

At Algiers, Bizerte, Naples, and other Mediterranean cities during World War II German bombers flew over harbors intent on blowing Allied shipping out of the water. In all but a relatively few instances they found nothing but an impenetrable haze covering the targets. On New Guinea and Luzon American paratroopers dropped safely to earth protected from bullets of Japanese riflemen by screens of white smoke. At beachheads, highways, and river crossings in Italy, France, and Germany, troops and trucks went about their work under a shield of artificial fog. Never before had armies been able to protect their troops and hide their movements as successfully as Allied forces did in World War II.

Military history records the tactical use of smoke in early times, but reliable smoke munitions are of fairly recent origin. Not until World War I did armies develop standard munitions and give them a wide trial. The British Army produced grenades and shells containing white phosphorus that emitted white smoke, and carbonaceous mixtures that gave off black smoke. The German Army, lacking phosphorus, depended on oleum, chlorosulfonic acid, and sulphur trioxide, all of which reacted with moisture in the air to form white fog. The French contributed Berger mixture, which threw off a gray smoke when heated. The American Army designed grenades, shells, candles, pots, and other munitions based on European originals, but did not get them to the battle zone in time for use. From the smoke munitions of World War I evolved most of the efficient screening devices used by friend and foe in World War II.

White Phosphorus

White phosphorus (CWS symbol, WP) is a soft waxy substance that reacts spontaneously with oxygen. When phosphorus is scattered from a bursting munition the heat of the explosion causes the phosphorus to

SMOKE POTS BEING SET OFF IN THE ARGONNE FOREST, *near Beaucamp, Meuse, France, October 1918.*

ignite as soon as exposed to air and throw off a dense white smoke of phosphorus pentoxide. The material WP was unsurpassed as a smoke producer and it also paid dividends in other ways. Burning phosphorus wounded enemy soldiers just as readily as rifle bullets and shell fragments. Fragments of burning phosphorus streaking through the air were also hard on enemy morale. For these reasons the CWS purchased two hundred million pounds of WP from 1942 to 1945, far more than any other smoke agent obtained during the war. [1]

The CWS used white phosphorus as a filling for shells, rockets, bombs, and grenades, all of which the armed forces employed extensively in World War II. Artillery and chemical mortar companies hurled shells to set fire to enemy held buildings and cane fields, to drive enemy soldiers from fortified positions, to unnerve enemy troops, to support infantry attacks, and to shield flame thrower operators. Naval vessels threw WP at shore installations on Saipan, Eniwetok, and other places to support amphibious assaults. The Army fired a sizable portion of the two and one-half million 2.36-inch rockets filled during the war to screen operations, to start fires, and to wound and unnerve the enemy. Airplanes dropped WP bombs on enemy installations to start fires or aid infantry. For infantrymen and

[1] Consolidated Chemical Commodity Report, p. 109.

marines, the CWS filled more than five million hand grenades and two million rifle grenades with WP, and, as indicated earlier, the American phosphorus was considered by the Germans, who were in a good position to know, of superior quality.[2]

Despite its excellence as a smoke agent, WP had a fault that brought objections from the field early in World War II. The smoke had a tendency in still air to rise into a pillar instead of lingering close to the ground where infantrymen wanted it. Pillaring depended primarily on the size of phosphorus fragments. If the bursting charge of a munition shattered the solid phosphorus filling into extremely fine particles, a large reactive surface area was exposed to the air. The large surface allowed the phosphorus to burn rapidly and in so doing give off a considerable quantity of heat which billowed the smoke upward. If, on the other hand, the explosion broke the phosphorus into a few large fragments, the exposed area was not nearly so great. The phosphorus then burned more slowly, emitted less heat, and the smoke hovered close to the ground.

The CWS tried various expedients to keep the explosion from completely shattering the phosphorus. In one experiment engineers stuffed wads of steel wool into a phosphorous shell to see if the network of steel threads would hold the phosphorus in chunks. In other tests they poured melted phosphorus into metal and paper tubes, and packed these tubes inside shells. None of the experimental shells was entirely successful and the problem remained unsolved until 1944 when the NDRC Munitions Development Laboratory at the University of Illinois devised a new filling consisting of small granules of phosphorus, about the size of grains of sand, suspended in a matrix of rubber. Explosion broke this filling, called plasticized white phosphorus, PWP, into chunks several millimeters in diameter that burned slowly for several minutes. Munitions loaded with PWP raised a better smoke screen than ordinary phosphorus munitions. Furthermore, the phosphorus, being in large pieces, was more effective against enemy troops. Although PWP was not completely satisfactory, since the phosphorus slowly separated from rubber in storage during hot weather, it was the best solution devised during the war.[3]

[2] (2) See Pritchard, Kleber, and Birdsell, Chemicals in Combat, a volume in preparation for the series UNITED STATES ARMY IN WORLD WAR II. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 14, 15, 26. (3) Ochsner, History of German Chemical Warfare in World War II, p. 33.

[3] (1) Benjamin C. Macintire, Navy 5-inch Smoke Projectile, WP-Filled, Engineering Tests. EATR 338, 8 Apr 41. (2) H. F. Johnston, Plasticized White Phosphorus, in *Military Problems with Aerosols and Nonpersistent Gases*. Summary Tech Rpt of Div 10, NDRC (Washington, 1946). (3) Noyes, *Chemistry*, pp. 277–78. (4) CWTC Item 1514, Standardization of Screening Smoke, PWP, 20 Dec 45.

The CWS produced a few hundred experimental 75-mm., 105-mm., and 155-mm. PWP shells in late 1944. The following year plants got into production and turned out 891,941 pounds of PWP. The service loaded this into mortar shells, recoilless mortar shells, bombs, and 3.5-inch and 4.5-inch rockets, but these appeared when the curtain was falling on the last act of the war and they were practically unknown to the fighting man.[4]

In contrast to the Americans and the British, the Germans did not have phosphorus ammunition. Germany lacked the raw materials for producing phosphorus, and its Army had to depend on less effective Berger mixture, described below, and on oleum. Grenades and smoke pots generally took a Berger-type filling, while mortar smoke ammunition, artillery smoke ammunition, and smoke rockets contained pumice saturated with oleum. The Japanese had a wide range of WP bombs, mortar shells, artillery shells, and grenades, but they used WP much less than the Americans did.[5]

Smoke Pots

Along with the first wide-scale use of white phosphorus as a smoke producer, World War I saw the invention of a new type of smoke agent, Berger mixture, by Capt. Ernest E. F. Berger of the French Army. The mixture, containing carbon tetrachloride, powdered zinc, and zinc oxide, was inert at normal temperatures, but when it was heated the ingredients reacted and gave off a dense gray smoke of carbon and zinc chloride particles.[6]

In the United States CWS chemists experimented with Berger mixture during the 1920's and 1930's and replaced carbon tetrachloride, a liquid, with hexachloroethane, a solid, to decrease evaporation during storage. (From the name hexachloroethane came the symbol HC employed by the American Army in designating this type of smoke agent.) By 1940 the service was using Type A HC containing hexachloroethane, zinc, ammonium chloride, and ammonium or potassium perchlorate, as a filling for smoke pots and other munitions. The fall of France cut off America's supply of imported perchlorate, and chemists began to search for substitutes. They chose calcium silicide, which Captain Berger had suggested

[4] (1) Consolidated Chemical Commodity Report, p. 109. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 5, 14, 15, 26, 28, 29, 30.

[5] (1) German Chemical Warfare Materiel, *passim.* (2) Japanese Chemical Warfare, *passim.*

[6] (1) Lt Col J. E. Zanetti, Notice sur les Appareils Fumigeres Utillisant les Compositions du Capitaine Berger, Z-206, 19 Jun 18. (2) George A. Richter, "Combustion Smokes," *Industrial and Engineering Chemistry,* 13 (1921), 343-45.

SMOKE SCREEN DEMONSTRATION *over the harbor, Palermo, Sicily. The screen was produced by mechanical smoke generators and smoke pots in thirteen minutes.*

back in World War I and which the British Army had adopted. The new mixture, designated as Type B HC, functioned satisfactorily but industrial firms had trouble producing it. They found that calcium silicide could be a dangerous material. When it was ground to a powder it reacted rapidly with oxygen in the air sometimes causing an explosion. Plants redesigned their equipment and took great precautions, but the danger led chemists to develop a safer mixture, Type C, containing grained aluminum, hexachloroethane, and zinc oxide. Then came the threat of a shortage of hexachloroethane. Chemists had to develop a substitute mix, Type E, with carbon tetrachloride replacing hexachloroethane. Actually the shortage of hexachloroethane never matured and the CWS was able to procure all the Type C mix it wanted. Engineers discovered that the new Type E mix could be loaded into bombs more easily than the other types, however, and the CWS used it extensively as a filling for M77 ten-pound bombs.[7]

[7] (1) Leo Finkelstein, "The Chemistry of HC Smoke Munitions," *Armed Forces Chemical Journal,* IV (October 1950), 16–18. (2) E. T. Lawrence, Development of HC Smoke Mixture. EACD 227, 3 Mar 25. (3) G. H. McIntyre, "Ferro's War Story," *Armed Forces Chemical Journal,* II (October 1947), 12–15. (4) Capt J. H. Hayes and Lt L. C. Andrews, Smoke Munitions for Airborne Operations. TDMR 823, 11 Apr 44.

With types A, B, C, and E HC mixtures, the CWS had a range of smoke agents suitable for hand grenades, rifle grenades, artillery shells, rockets, bombs, and smoke pots. Shells, grenades, and bombs found employment during the war but by far the most widely used HC munition was the smoke pot.

At the time of Pearl Harbor the CWS's standard smoke pot, M1, was a cylindrical can 8 inches high and 5 inches in diameter, holding about 10 pounds of HC. Fired by hand or electric current, it released a cloud of grayish white smoke for a period of 5 to 8 minutes. The service had devised this pot in the early 1930's as a munition for training exercises, but when war came it was the only munition of its type available and the American Army took it along to North Africa.[8]

Because they released smoke immediately, pots were useful in setting up a preliminary screen during the five or so minutes that it took large mechanical generators to warm up and start functioning. They helped shield harbors and installations on the coast of North Africa as well as at the harbors at Palermo, Licata, and Porto Empodocle on Sicily.[9]

Before the landings on Italy, troops employed smoke almost exclusively for harbor defense and only to a minor degree in amphibious operations. But at Salerno, where the enemy kept beaches under observation for two weeks, the Army used smoke along the shore to protect incoming landing craft from enemy bombers, machine guns, and artillery fire. The small size and light weight of pots enabled troops to carry them ashore and employ them until heavy, bulky, mechanical generators could be landed. After Salerno, smoking of invasion areas by army units and by naval support boats became a standard practice on the coast of Europe and on Pacific islands.[10]

In Italy pots also graduated from harbor defense and invasion defense to forward area defense. Troops employed them to screen supply routes, bridge construction, river assault crossings, tanks, ammunition dumps, troop concentrations, ground operations, and even to hide mortar flash. As a result of the wide usage of pots under many conditions, the CWS learned of minor flaws in the design of the munition. Those that were opened in anticipation of combat could not be resealed tightly. Moisture from the air crept under the lid, disintegrated the matchhead and rendered

[8] (1) TM 3-300, 13 Apr 42. (2) CWTC Item 943, Standardization of Pot, Smoke, HC M1A1, 17 Mar 44.

[9] Paul W. Pritchard, Smoke Generator Operations in the Mediterranean and European Theaters, Chemical Corps Historical Studies No. 1, pp. 37-46.

[10] Pritchard, Kleber, and Birdsell, Chemicals in Combat.

SMALL M1 SMOKE POTS SET OFF IN A SERIES *to maintain a screen for troops in the Gothic Line, Italy.*

the pots useless. Furthermore, handles protruding above the lids made it impossible to stack the pots. To overcome these defects engineers substituted a flat screw-type lid without handles that could be resealed, and allow pots to be placed one on the other. The revised model bore the designation M1A1.[11]

In addition to these flaws, smoke pots at times proved to be smaller than troops desired. More men were required for maintaining a smoke screen with small pots than with large ones. In 1944 the CWS began to turn out pots holding three times as much HC, and burning twice as long. Almost a million large pots, designated as model M5, came from filling lines before the war ended. They did not reach Europe in appreciable quantities before V-E Day, and the original M1, of which more than five million were produced, remained the workhorse of ground troops.[12]

[11] (1) CWTC Item 943. (2) A photograph showing troops using type M1 pots to screen infantry crossing the Rapido River, Italy, may be found in *The War Against Germany and Italy: Mediterranean and Adjacent Areas,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1951), p. 227.

[12] (1) CWTC Item 926, Standardization of Pot, Smoke, 30-lb, HC, M5, 21 Jan 44. (2) Capt J. H. McLain and Lt E. R. Padavic, Pot, Smoke, HC, M5. TDMR 817, 24 Mar 44. (3) TB 3-300-1, HC Smoke Pot, M5, 27 May 44. (4) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 23.

Although HC was regarded as nontoxic as the other CWS screening agents (titanium tetrachloride, chlorosulfonic acid-sulphur trioxide, and white phosphorus), its use in troop training exercises showed that when breathed in a confined area it might produce fatalities through extreme lung irritation. The airborne particles of zinc chloride that were dispersed during the burning of HC were believed to be the only toxic element, until further tests revealed that hexachlorothane mixtures contaminated with ammonium chloride were even more lethal. Wearing the gas mask in HC smoke clouds provided adequate protection, and the Army changed manuals and other training literature accordingly.[13]

The German Army did not have as large a variety of HC-type smoke munitions as did American forces. Smoke bombs, grenades, and candles (analogous to U.S. pots) made up the list, and of these the infantrymen depended generally on the candle. Type 39 candle, a metal cylinder slightly over 5 inches in height and 3 inches in diameter, held sufficient HC-type mixture to burn for 4 to 7 minutes. Armored vehicles carried modified type 39 candles containing a mixture that burned more rapidly. Type 42 candle, produced late in the war, was a much larger munition, burning for 20 to 25 minutes.[14]

The Germans had a variety of launchers capable of tossing smoke pots 25 to 300 yards. These were first designed for armored vehicles. The original model was a bracket fastened to the side of the vehicle with 3 cups to hold candles. The device had to be loaded from the outside and was fired electrically, the candle being ignited and hurled about 25 yards by a charge of black powder. A later model resembled a miniature cannon. It was attached to a vehicle by a ring mount, and was loaded through the breech. Toward the end of the war, launchers for ground troops made their appearance. These were little more than crude mortars. The operator placed a powder charge in the bottom of the launcher barrel and then dropped an ignited smoke candle down the barrel, setting off a blast which threw the candle up to 300 yards.[15]

The German Army's use of smoke pots was not unlike that of the American Army. Troops used smoke to cover withdrawals, as at Metz, to screen troops and supply movements against observation and air attack, to permit tanks to disengage from the enemy, and to divert the enemy's attention and fire. As early as 1943 the production of smoke pots had

[13] Toxicological Research Laboratories. Informal Monthly Progress Report 2, 15 Jun 44.
[14] German Chemical Warfare, pp. 135–37.
[15] (1) *Ibid.* (2) German Chemical Warfare Materiel, pp. 1–K–6 – I–K–9.

fallen behind the demand, and through the remainder of the war the German Army was unable to expend smoke with the same liberality as the American Army.

The Japanese Army had among its munitions grenades, candles, bombs, and shells filled with Berger-type or HC smoke mixtures. For producing screens it favored candles, of which there were 3 major types: the self-propelled candle, the rifle-launched candle, and the stationary candle. The self-propelled candle held 1½ pounds of smoke mix in one end and a propelling charge at the other capable of hurling the munition a distance of 130 to 300 yards, according to the angle at which it was fired. The rifle-launched candle was a cylinder 2 inches in diameter, 6 inches long, filled with smoke mix, and carrying from 45 to 200 yards, depending upon the adjustment of a heavy grenade launcher. Stationary candles came in 2 sizes, one holding 2 pounds of smoke agent, the other 7 times this quantity.[16]

While the Japanese gained considerable experience with smoke in their early campaigns against the Chinese, they made little use of it against American forces in the Pacific. Army and Navy raiding parties sometimes carried smoke grenades, ground troops on several occasions used smoke to confuse American air crews as to targets previously marked with smoke by American forces, and on Okinawa they screened local counterattacks and attempts at infiltration. The failure of the Japanese to make greater use of smoke screens in their tactics is surprising in view of the ample supplies of smoke munitions captured in Japanese ammunition dumps on Leyte, Luzon, and other islands.

The Army and Navy needed floating smoke pots to screen amphibious forces from enemy observation posts and artillery fire. Harbor defense units needed floating pots to assist in maintaining smoke rings against enemy planes. For these reasons the CWS undertook the development of this type of munition in 1942.

Engineers constructed the first experimental munitions from metal drums ballasted with concrete and loaded with HC. When tests proved these pots too heavy and difficult to handle, engineers simplified the design by discarding the concrete and only partially loading the drums so they were bottom-heavy and floated upright. The final model, M4, was a 5-gallon steel pail containing 26 pounds of smoke mix. To generate smoke the operator jerked a fuze wire extending through a hole in the lid and

[16] WD Intel Bull, Sep 45, pp. 78–84.

TROOPS LANDING AT ELBA, JUNE 1944. *Note HC floating smoke pot at left of the LCI's.*

tossed the can into the water. The pail bobbed to the surface and poured out white smoke through vents in the lid for ten to fifteen minutes.[17]

When floating pots came off the production line and entered supply channels, the Army and Navy found fault with the design. If the munition was handled roughly its HC filling crumbled, and the pot would not generate smoke. On several occasions firing mechanisms went off accidentally, igniting the pots and starting fires in warehouses, docks, and ships. To improve the munition, engineers placed a perforated, circular steel plate on top of the filling to hold it in place and devised a safer firing mechanism. The modified munition passed rough-handling tests satisfactorily and was standardized as the M4A1 in July 1943.[18]

[17] (1) CWTC Item 561, Standardization of Pot, Smoke, Floating, HC, M4, Military Requirement and Military Characteristics, 29 Sep 42. (2) W. H. Flegenheimer, Development of a Floating Smoke Pot. TDMR 510, 6 Mar 43.

[18] (1) Capt J. H. McLain and Lt E. R. Padavic, Development of an Improved Floating Smoke Pot. TDMR 822, 5 Apr 44. (2) Ltr, Port Ord Office, Brooklyn, N.Y., to OC Ord, 22 Mar 43, sub: Malfunction of HC Floating Smoke Pot, M4. Cited in ref d, CWTC Item 725. (3) Ltr, CG Hawaiian Dept to Pres CW Board, 12 Apr 43, sub: Malfunctioning of Pots, Smoke, Floating, HC, M4. CWS 470.71. (4) CWTC Item 725, Standardization of Pot, Smoke, Floating, HC, M4A1, 1 Jun 43. (5) CWTC Item 781, same title, 23 Jul 43. (6) TM 3-300, 1 Mar 44.

The service found another source of trouble in the composition of the smoke mixture. Type B HC, the first filling used in floating pots, contained calcium silicide which could react with moisture in the atmosphere and generate hydrogen. Hydrogen and the air beneath the lid produced an explosive mixture. When the operator pulled the fuze wire the flame ignited the mixture, causing an explosion that sometimes blew the lid off the pot. As a precaution the CWS told operators to take off the lids and allow the hydrogen to escape before employing the smoke pots. This was inconvenient, particularly when a large number of pots had to be vented. The trouble was finally eliminated when chemists developed Type C HC to replace Type B.[19]

One other flaw in the floating pot was rather minor, yet it caused considerable annoyance to those who handled the munitions. The fuze stuck out from the center of the lid, preventing pots from being stacked in piles, and sometimes causing it to get knocked out of place. Engineers remedied this by lowering the fuze into a shallow well. This final model of the floating pot, designated as M4A2, was ready in March 1944.[20]

American forces used floating pots soon after they arrived in the Mediterranean area. After the invasion of Sicily naval patrol boats helped maintain smoke screens surrounding the harbors at Licata and Porto Empedocle by means of floating pots. At Salerno support boats dropped floating pots to form a screen that would protect landing craft from machine gun and artillery fire. The Third Army in its drive across France into Germany employed thousands of floating pots in assault river crossings, bridge construction, ferry operations, and other missions. The Ninth Army employed several thousand pots in crossing the Roer and Rhine rivers. Other armies set up floating screens whenever the occasion demanded. Since floating pots functioned on land as well as on water, troops often employed them in place of standard land pots when supplies of the latter ran low. While the M4 floating pot did not have the all-around usefulness of M1 and M5 land pots, it was a valuable munition in certain situations and it repaid the time and labor that went into its development and production.[21]

The German Army did not have floating munitions of the American

[19] (1) Lt H. Barnard, Pot, Smoke, Floating, HC, M4—Aluminum (Secondary), Zinc Oxide, Hexachloroethane Filling. TDMR 489, 19 Dec 42. (2) TM 3-300, 1 Mar 44.

[20] (1) McLain and Padavic. TDMR 822. (2) CWTC Item 934, Standardization of Pot, Smoke, Floating, HC, M4A2, 17 Mar 44. (3) TB 3-300-2. HC Floating Smoke Pot M4A2, 1 Jul 44.

[21] (1) Pritchard, Smoke Generator Operations, pp. 44, 53, 170-71, 184. (2) *After Action Rpt, Third U.S. Army, 1 Aug 44–9 May 45*, vol. II, pt. 11, p. 10.

type which gave off smoke from a burning mixture, but they had a smoke float that generated white smoke by the action of water on fuming sulphuric acid or oleum. The float was a drum about 30 inches high, a foot in diameter, weighing 40 pounds empty and 80 pounds loaded. An inner container held the oleum which reacted with water, and emitted smoke for 8 to 9 minutes. The disadvantage of this type of munition lay in the corrosive action of the acid. [22]

Japanese troops were supplied both with floating pots that produced smoke from a burning mixture, and with floating generators that produced smoke by action of water. The Japanese floating pot, designed for use at sea or in rivers and harbors, was a long metal tube filled with eleven pounds of smoke mixture similar to the HC mixture used by the CWS. The novelty of the pot lay in the method of floatation. The pot fitted into a doughnut shaped, inflatable, rubber ring that held it upright and kept it from sinking to the bottom. [23] The generator was a steel drum about a foot in height and in diameter, weighing ninety pounds when filled with fuming sulphuric acid. An inflated rubber ring could be attached to the float to increase its buoyancy. A small device inside the lid contained a material that burned slowly, giving off considerable gas. This gas built up pressure in the drum and forced the acid up a pipe that protruded above the float. Upon contact with air the acid formed a dense white cloud. [24]

Japanese and German forces did not employ floating smoke pots as extensively as American troops did. Early in the war enemy troops advanced and made amphibious landings without serious resistance, so that such aids as floating pots seemed unnecessary to them. Later as they retreated stubbornly and the American forces advanced, it was the Americans who used smoke pots to the best advantage.

Oil Smoke Generators

Smoke produced by the combustion of chemical mixtures was not the perfect answer to screening because mixtures were expensive, the smoke nauseated the troops, pots burned out in a short time, and many men were needed to maintain a large screen. On the other hand, it was easy and cheap to produce smoke by burning oil, and in 1941 the CWS stand-

[22] Tactical and Technical Trends, no. 23, 22 Apr 43, p. 7.
[23] WD Intel Bull, Jun 43, pp. 47–49.
[24] Japanese Chemical Warfare.

ardized an oil burner for this purpose. The Stationary Oil Smoke Generator, as the device was called, consisted of a sheet-iron pot about 2 feet in diameter and topped by a smokestack 3 feet high. The pot held about 15 gallons of crude oil. When the oil was ignited a mixture of black carbon smoke and oil droplets raced up the chimney and billowed out into the air. The volume of smoke was about equal to that given off by the M1 pot. The generator functioned like the smudge pots used in the South, to help protect citrus groves against frost. The British had produced a considerable number of similar smoke generators for defense of their island, and this was one of the factors that led the CWS to adopt this device.[25]

A few months after Pearl Harbor the CWS organized smoke generator companies, equipped each company with 3,600 oil smoke generators, and stationed them at the Panama Canal, the Sault Ste. Marie Canal, and around aircraft factories on the west coast. The generators did not go outside the continental United States or the Canal Zone. In maneuvers troops found that the large, heavy generators could not be moved quickly when the wind changed direction. Furthermore, the black smoke that they emitted did not have the obscuring power of white smoke. These disadvantages led the service to adopt a mechanical smoke generator in 1942 and abandon the stationary generator in 1944.[26]

Mechanical smoke generators came into existence through the co-operative efforts of industry, the National Defense Research Committee, and the CWS. The principle behind the device was simple. It vaporized a mixture of water and oil (the CWS used a special oil commonly referred to as fog oil), and then discharged the mixed vapors into the air. When the hot vapor hit the cool air it condensed back into tiny liquid droplets.

Mechanical generators had many advantages over oil burning generators. They produced smoke more rapidly and in larger quantity so that fewer men could screen a larger area. Their smoke was very persistent. By way of comparison, smoke from HC pots was seldom effective for more than 500 to 800 yards downwind, while smoke from mechanical generators extended for several miles.

Development of the first mechanical generators took more than a year. In 1941 the CWS received reports from the British of the Haslar genera-

[25] (1) CWTC Item 357, Standardization of Generator, Oil, Smoke, M1, 22 Jul 41. (2) CWTC Item 403, same title, 14 Oct 41. (3) Brooks F. Smith, Engineering Test of Kincaid Oil Smoke Generators. TDMR 265, Jan 41.

[26] (1) CWTC Item 1010, Obsoletion of Generator, Oil, Smoke, M1, 5 May 44. (2) CWTC Item 1073, same title, 7 July 44.

MECHANICAL SMOKE GENERATOR M1 (100-GALLON) *pouring out smoke screen to conceal Fifth Army operations from the Germans, Anzio area, Italy, March 1944.*

tor, a 14-ton, cumbersome monster that produced dirty brown smoke from fuel oil and water. The CWS undertook the development of a generator based on the Haslar. In the meantime the NDRC, which had established a project on smokes and filters in 1940, was making progress on a different kind of generator. Associated with the NDRC were Irving Langmuir of General Electric Co. and Victor La Mer of Columbia University. These men and their associates studied the size and color of particles in artificial fogs to find the properties of droplets essential for maximum screening ability. Their final determinations ended the search for the ideal properties of particle size and color. They began their analysis with the knowledge that the effect of a smoke screen on the eye was partly physiological, partly optical, and partly psychological. Light from the sun struck the smoke, some of it passing through untouched, the remainder scattering in all directions. A person trying to concentrate on a target saw not only light reflected from the target but also the scattered light. The intensity of the scattered light determined the effectiveness of the screen in confusing and disorting the image. In their experiments, Langmuir and La Mer found that white particles .3 micron in radius produced the proper scattering effect.[27]

Langmuir and his co-worker Vincent J. Schaefer then devised a small generator capable of producing fog particles of the desired size. The model turned out a smoke screen much thicker and more permanent than the screen from the current oil burning generator. Upon request from NDRC the Standard Oil Development Co. rushed a full-size generator to completion in six weeks. In tests the generator performed so well that the CWS asked Esso to begin production at once. To obtain generators quickly, the CWS by-passed procedures generally followed in development, and engineers made last minute changes in design at the plant. In December 1942 the service standardized the apparatus for military use.[28]

Mechanical Smoke Generator M1 stood six feet high, weighing 3,000 pounds empty and 5,400 pounds filled. It had to be transported by a trailer, truck, or barge. At full capacity it consumed 100 gallons of fog oil, 7 gallons of fuel, and 150 gallons of water per hour. After starting, three to

[27] (1) Baxter, *Scientists Against Time*, pp. 283–86. (2) *Military Problems with Aerosols and Nonpersistent Gases*. (3) Noyes, *Chemistry*, 278–81.

[28] (1) Invention Report of Aerosols: I. The Langmuir-Schaefer Smoke Generator, NDRC Division 10, Miscellaneous Pub. No. 270, 30 Apr 43. (2) W. H. Rodebush, V. K. La Mer, Irving Langmuir, and T. K. Sherwood, Screening Smokes. OSRD 940, 5 Oct 42. (3) CWTC Item 574, Standardization of Mechanical Smoke Generator, 24 Nov 42. (4) CWTC Item 646, same title, 12 Jan 43.

six minutes elapsed before it warmed up and threw out an effective smoke screen.[29]

Generators first saw action in North Africa where CWS units used them in the smoke defense rings around Oran, Algiers, Bône, Bizerte, and other harbors. Later, the service used them for the invasion of Sicily. At Paestum in Salerno Bay, generator units operated for the first time under artillery fire, effectively concealing the anchorage and unloading areas from the Germans. The operation worked out so well that the Army decided to include a smoke unit in the forces assembled for the Anzio landing. In March 1944 mechanical generators threw up a protective haze between the town of Anzio and enemy lines. Thereafter the Army employed generators in front-area operations and to shield troop and convoy movments.[30]

The wide use of M1 generators in all kinds of weather and on all kinds of terrain in North Africa, Sicily, and Italy revealed shortcomings in the device. Mechanical flaws that normally would have shown up in development tests and have been corrected before the item was issued to troops now popped up in battle. More important, the heavy weight of the generators and the length of time they needed to warm up sometimes delayed the rapid deployment of troops, and on occasion prevented them from moving generators about on the battlefield. As a result the CWS and NDRC intensified their efforts to produce a lighter, compact generator that could be moved easily and make smoke quickly.[31]

In May 1943, the DeVilbiss and York-Hessian Companies built, under NDRC contract, small generators for trial. In September the Besler Corp. delivered to the CWS an experimental generator that the corporation had originally developed for the U.S. Navy. In comparative tests the Besler generator came out on top, and in January 1944 the CWS standardized it as model M2. The new generator was less than 3 feet long, 2 feet wide and 2 feet high. It consumed 50 gallons of fog oil, 5 gallons of gasoline, and 5 gallons of water per hour. Weighing only 180 pounds empty, 266 pounds full, it could be carried short distances by two men, whereas the M1 needed a vehicle. It could be employed in mountainous country or on soft ground, whereas the M1 could only be used on fairly flat, firm

[29] TM 3-380, 12 May 43.

[30] (1) Pritchard, Smoke Generator Operations, pp. 37-83. (2) Pritchard, Kleber, and Birdsell, Chemicals in Combat, ch. VI. (3) *The War Against Germany and Italy*, pp. 262-63. (4) "American Forces in Action Series," *Anzio Beachhead (22 January-25 May 1944)*, p. 110. (5) Charles B. MacDonald and Sidney T. Mathews, *Three Battles, Arnaville, Altuzzo, and Schmidt*, UNITED STATES IN WORLD WAR II (Washington, 1952), pp. 65-70.

[31] Capt T. L. Hurst and 1st Lt W. F. Kozak, Inspection of Mechanical Smoke Generator M1 (Esso) After Extensive Service. TDMR 644, 7 Jun 43.

MECHANICAL SMOKE GENERATOR M2 (50-GALLON), *one of many used to screen a heavy ponton bridge over the Rhine River, Germany.*

ground. It produced smoke in less than 1 minute in contrast to the M1 which needed 3 to 6 minutes. On top of all these advantages it was simpler to operate and maintain in working order.[32]

The Fifth Army in Italy issued M2's to smoke units in August 1944. The First Army received them in time for the landings in Normandy. As units received M2's they gradually substituted them for M1's. But all was not well. In action the new generators did not perform as efficiently as had been expected. They produced smoke for a few days, and then stopped. Frequently the coils in which the oil-water mixture was heated kept burning out. Poorly trained, careless operators caused some of the breakdowns while defects in the design of the generator caused others. As reports came in from the field, engineers at Edgewood corrected minor faults in the generator, though by the end of the war they were still not able to prevent coils from burning out.[33]

[32] (1) Capt T. L. Hurst, Capt Winton Brown, and H. E. Norton, Development of a Lightweight Portable Oil Smoke Generator of Fifty Gallon Per Hour Capacity. TDMR 810, 1 Mar 44. (2) TM 3-381, 14 Jun 44. (3) CWTC Item 864, Standardization of Generator, Smoke, Mechanical, M2 (50 Gallon), 3 Dec 43.

[33] (1) Col William H. Green, "Make Smoke," *Chemical Warfare Bulletin* 31 (Jan–Feb 45), 21–24. (2) *The War Against Germany and Italy,* p. 381.

The Germans had large smoke generators for shielding oil refineries, blast furnaces, factories, canals, docks, and other important bomber targets. The principle behind their generators was entirely different from the one used by Americans. Instead of using oil they employed an acidic solution which fumed in moist air. The acid was stored in large barrels fitted with spray nozzles and connected to cylinders of compressed air which forced the acid out through the nozzles. Smoke from these sprayers has been described as resembling tobacco smoke. With a twenty-gallon drum of acid, a screen could be maintained for more than an hour. They did not generate smoke as rapidly as mechanical generators, the average length of time needed to set up an effective screen being fifteen minutes.[34]

German defenders ringed Berlin, Gdynia, Warnemunde, and other vital cities with acid spray generators generally spaced seventy-five to one hundred yards apart. At harbors such as Brest, sprayers on docks, breakwaters, and small fishing boats helped maintain the defensive circle. The smoke screens were not as thick as those thrown up by American mechanical generators, but the records show that they were helpful in cutting down the effectiveness of American bombing raids.[35]

The mechanical smoke generator was one of the innovations of World War II. It added a new dimension to smoke operations, making it possible for the Army to mass produce smoke for tactical and strategic operations. Judging from the increased use of generators as the war progressed, it seemed highly probable that mechanical smoke generators would be a standard piece of equipment in any future war.

Airplane Smoke Tanks

While smoke screens on land and sea were not new at the time of World War II, air screens were an innovation. Such screens, or curtains as they were frequently called, were set up by low-flying airplanes spraying liquid smoke-producing chemicals into the air. As the droplets floated to earth they reacted with moisture in the atmosphere and formed white smoke that hung suspended in the sky like a high, wide curtain.

The CWS began work on air smoke back in World War I when the Army considered smoke signals as a possible means of communication between planes or between planes and the ground. The service experimented with the idea, dropped it after the armistice, and then took it

[34] (1) Military Intelligence Div, WD, Special Series No. 24, Enemy Tactics in Chemical Warfare, 1 Sep 44, pp. 53–54. (2) Tactical and Technical Trends, no. 24, 6 May 43, pp. 8–11. (3) German Chemical Warfare Materiel, pp. I–L–1–I–L–5.

[35] *The War Against Germany and Italy*, p. 393.

up again in 1923 when the Navy asked for a smoke signaling device that could be mounted on a seaplane. During trial flights, engineers found that signal smoke formed so readily and had such good quality that it was worth investigating as screening smoke. The CWS continued to develop apparatus for airplane smoke screens long after the idea of smoke signals had been forgotten.[36]

Early devices injected liquid smoke agents into the exhaust of the plane. These soon gave way to simple spray tanks that emptied their contents directly into the air. The development of smoke tanks then received impetus from the fact that they could also be used to spray liquid toxic agents, such as mustard, on enemy troops. In other words, the Army could employ them on defensive missions to drop air curtains, or on offensive missions to drop toxic chemicals. In World War II the Army and Navy employed tanks only for the former purpose, but they were on hand in case gas warfare broke out.

The CWS had two smoke agents for spraying. Titanium tetrachloride (symbol FM) had been known to chemists for almost a century before European armies placed it in World War I artillery shells to throw up a white smoke and thus assist observers in directing fire. It reacts immediately with water vapor, forming several white compounds that remain suspended in air as a dense white cloud. The service employed FM as its first agent in the 1920's, but the disadvantages—excessive cost and the tendency of solid reaction products to clog spraying apparatus—sent chemists in search of a replacement. In 1930 the service decided on FS, a solution of sulphur trioxide in chlorosulfonic acid. When atomized in moist air the ingredients reacted with water vapor forming minute droplets of sulphuric acid that, like FM, also appeared as a dense white cloud. During World War II the CWS procured supplies of both agents, two thousand tons of FM, and twenty-four thousand of FS (some of which went into smoke bombs and grenades).[37]

The standard airplane spray tank was, at the time of Pearl Harbor, model M10, holding about thirty gallons of liquid and streamlined in accordance with formulas recommended by the National Advisory Committee on Aeronautics. The CWS had begun development of this tank in 1937 at the request of the Air Corps and later, lacking time and person-

[36] (1) F. R. Weaver, The Development of a Screening Smoke Generator for Type F-5 Sea Planes. EACD 268, 27 Mar 23. (2) Harry O. Huss, "Airplane Spray Apparatus: The Evolution of the Ram Gravity-Type Smoke Tank," *Armed Forces Chemical Journal*, III (April 1950), 10–15, 32–33.

[37] (1) TM 3-215, Aug 52. (2) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

LOCKHEED A-29 SPRAYING SMOKE FROM M33 SMOKE TANKS *visible under wings of craft. Smoke tank protruding from bomb bay is the M33 A-1.*

nel, had contracted with the Douglas Aircraft Co. to complete it. The A-20 Douglas Havoc or any other plane equipped with suitable carrying racks and controls could take the spray tank aloft. An inlet in the front admitted air, and an outlet in the tail pipe released the spray. Glass disks blocked both holes until the pilot pressed an electrical switch, sending a current through detonators attached to the glass. Air rushed through the inlet into the tank forcing the filling out through the tail pipe. The rate of discharge varied with the velocity of the plane, dropping from 5½ seconds at 175 miles per hour to 4 seconds at 325 miles per hour. With FS smoke agent, the maximum height at which the plane could fly to produce an effective curtain was about 300 feet. Some of the smoke billowed upward so that the completed screen towered about 400 feet in the air and stretched about 2,000 feet along the ground. Model M10 was the most popular of the CWS's smoke tanks, more than 90,000 coming from plants during the war.[38]

While the CWS was readying a smoke tank for the Army, the Navy,

[38] (1) CWTC Item 13, Tanks, Airplane Chemical Spray, Approval of Military Characteristics, 3 Aug 37. (2) TB 3-255A-1, Airplane Smoke Tank M10, 8 Nov 44. (3) Capt H. E. Lott and Harry O. Huss, FS Smoke Curtains from Airplane Spray Tanks M10 and M33. TDMR 805, 7 Mar 44. (4) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 24.

which had never lost its early interest in air curtains, designed two tanks somewhat larger and based on a different principle than the CWS's M10. One of these held fifty gallons, the other thirty gallons. The plane carried a cylinder of compressed carbon dioxide gas, the pressure of which ejected the smoke agent. With this system the pilot could turn the spray tank on or off at will, releasing the agents in puffs or in one long burst.

The CWS adopted the Navy tanks for the Army, modifying them for bomb bay installation (the Navy used belly mounting) and designating them as models M20 and M21. In 1942–43 the service procured more than six thousand of each model. Experience showed that the tanks were cumbersome, the cylinders of carbon dioxide were an annoyance in supply channels, and the smoke screens were not sufficiently thick. The CWS stopped production of the tanks and declared them obsolete in 1944.[39]

The tanks that have been mentioned were designed originally for external mounting on planes. Some years before the war the CWS had considered mounting tanks in bomb bays for smoke spraying or toxic spraying, but it discarded the idea because of the danger to crew and plane in case the tank was pierced by enemy fire. In 1939 a conference of Air Corps and CWS officers decided to go ahead with the idea. The work proceeded slowly owing to a combination of circumstances: the runway at Edgewood Arsenal had to be enlarged to accommodate multi-engine planes, the CWS had to obtain an isolated proving ground for high altitude spray tests, and the Army needed bombers abroad so badly that it would not assign one for the test project. Not until 1942 was the experimental model ready, and not until 1944 did production begin. This new tank held seventy gallons of agent, and could set up a smoke screen 400 feet high and 4,000 feet long in one minute. The bombardier could drop the tank if necessary before or after the mission. Later the CWS modified the tank so that it could be suspended from wings of aircraft, and thus decrease contamination of the plane from spattering and lessen the danger to aircrews. Industry produced more than ten thousand of the bomb bay type (M33) and wing type (M33A1).[40]

[39] (1) CW TB 13-1-3, Airplane Smoke Tanks, M20 and M21, 18 Jul 42. (2) CWTC Item 503, Standardization of Airplane Smoke Tank, M20A1 and M21A1, 2 Jun 42. (3) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 24. (4) CWTC Item 1129, Obsoletion of Tanks, Airplane, Smoke, M20, M20A1, M21, M21A1, and Related Handling Equipment, 31 Aug 44.

[40] (1) Ltr, Lt Gen Delos C. Emmons to Chief Air Corps, 25 Jan 41, sub: High Altitude Chemical Spray, with 5 inds. AF 470.7 (1-25-41). (2) CWTC Item 633, Standardization of M33 Airplane Smoke Tanks, 12 Jan 43. (3) TB 3-255B-1, Airplane Smoke Tanks AN-M33A1 and M33, May 45. (4) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 24.

The M10, M20, M21, and M33 smoke tanks gave the Army a range of from thirty to seventy gallons, but wartime bombers were capable of carrying tanks of considerably greater size. Accordingly the CWS designed and tested, but did not produce in quantity, a tank (M40) holding more than 200 gallons (4,000 pounds) of FS for B-17 and B-24 airplanes. With its large capacity, this tank could set up a screen much longer and thicker than could smaller tanks.[41]

The armed forces used aerial smoke curtains on many operations in Europe and in the Pacific. In the Marshalls carrier planes laid screens to shield landings at Roi-Namur. As a prelude to amphibious landings on Guam, Okinawa, and Borneo, planes laid down smoke to conceal underwater demolition teams. In Italy the Air Forces placed a screen behind Cisterna to shield the 7th and 15th Infantry. At Nadzab, near Lae, New Guinea, at Kamiri airstrip, Noemfoor, and at the Camalaniugan airfield near Aparri, Luzon, aircraft sprayed smoke to protect paratroop landings.[42]

American forces far outdid German and Japanese armies in the use of aerial smoke screens in World War II, although the enemy was also equipped for such operations. The Germans had several spray tanks of different sizes which, like American tanks, could have been used for toxic agents or smoke agents. Their liquid agent was a solution of sulphur trioxide in acid, similar to the CWS's FS smoke agent. The Japanese had at least one aircraft spray device, as well as agents like FS and FM. The reason the Germans did not use aerial smoke seems to have been the fact that their armies had been successful in invasions and paratroop drops, as at Crete, without smoke curtains, and by the time they had learned the value of such curtains from American successes, they were on the defensive. The Japanese could have employed aerial smoke on many of their island invasions, but again their success in invasion by conventional means may have made them oblivious of the potential value of air curtains.[43]

[41] (1) CWTC Item 792, Standardization of Tank, Airplane Smoke, M40, 3 Sep 43. (2) Huss, "Airplane Spray Apparatus."

[42] (1) Wesley Frank Craven and James Lea Cate, eds, "Army Air Forces in World War II," vol. IV, *The Pacific: Guadalcanal to Saipan, August 1942 to July 1944* (Chicago: University of Chicago Press, 1950), pp. 185, 659. (2) Wesley Frank Craven and James Lea Cate, eds, *The Pacific: Matterhorn to Nagasaki*, p. 456. (3) *The War Against Japan*, pp. 166–67, 378. (4) *United States Sixth Army, Report of the Luzon Campaign*, vol. 3, p. 90. (5) Lt Col Robert D. Heinl, Jr., and Lt Col John A. Crown, "Marine Corps Monographs," *The Marshalls: Increasing The Tempo* (Washington, 1954). (6) *Anzio Beachhead*, p. 33. (7) Appleman, Burns, Gugeler, and Stevens, *Okinawa: The Last Battle*, p. 65. (8) Maj O. R. Lodge, "Marine Corps Monographs," *The Recapture of Guam* (Washington, 1954), p. 34.

[43] (1) Enemy Capabilities for Chemical Warfare, p. 124. (2) New Notes on German Chemical Warfare (London, British War Office [M110], May 1943) sec. 7 (c) (VIII).

Airplane spray tanks were not as widely or as frequently employed as smoke pots, grenades, mechanical generators, and other ground smoke munitions. In amphibious landings, paratroop drops, and situations where a wall of protective smoke had to be erected quickly between American and enemy forces, smoke tanks nonetheless proved to be valuable, efficient devices.

Colored Smoke Munitions

The Chemical Warfare Service's experience with colored smokes began in 1917 when it developed red, yellow, blue, green, and black smoke signals for the AEF.[44] In carrying out this work the CWS stepped into a field of munition research already occupied by the Ordnance Department. Therefore in 1920, when Congress made the CWS a permanent branch of the Army, the War Department found it necessary to set up a boundary between the two organizations. The Secretary of War assigned to the Ordnance Department all smoke devices used in signaling and spotting, to the CWS all smoke devices used in screening.[45] As a result of this ruling and of a lack of interest on the part of the using arms the CWS did little with colored smokes during the 1920's and 1930's. But shortly before World War II the service received requests from the Army Air Forces and from the Armored Force for colored smoke munitions. With the co-operation of Ordnance, CWS again undertook work on colored smokes.[46]

During World War II, colored smoke grenades were the signal munitions most commonly used by American troops. The CWS began development in September 1942 when the Army Ground Forces requested smoke grenades that could be used to show troop positions, to identify American tanks, or to signal the location of forced-down planes. The major problem facing the service was to find a mixture of chemicals that would produce smoke of the desired color, volume, visibility, and duration. This necessitated a search for heat-stable, commercially available, inexpensive dyes, and for a fuel which would burn with sufficient intensity to volatilize but

[44] (1) Arthur B. Ray, "Production of Colored Smoke Signals," *Industrial and Engineering Chemistry* 18 (1926), 10–17. (2) Arthur B. Ray, "Signal Smokes," Chemical Warfare Monograph, vol. 41, pts. 1 and 2, May 1919. (3) Leo Finkelstein, Colored Smokes.

[45] WD GO 54, 28 Aug 20.

[46] (1) CWTC Item 568, Standardization of Grenade, Smoke, Red, AN–M3, 29 Sep 43. (2) Col Robert D. McLeod, Jr., "Colored Smoke," *Armed Forces Chemical Journal*, VIII (Jan–Feb 54), 10–12.

not to decompose the dye. Dyes were not synthesized in the Edgewood laboratories, but were obtained from industry. Industrial co-operation was extremely important since the CWS needed a large quantity of dye. For example, since each colored smoke grenade required seven-tenths of a pound of dye the CWS had to purchase approximately three and one-half million pounds of dye to fill the five million grenades produced during the war. Other signal muntions greatly increased the total poundage of dyestuffs so that industry had a problem in producing all the special dyes that the CWS needed.[47]

Engineers fashioned the first smoke grenades from the standard chemical warfare M7 grenade. This was a steel cylindrical can 4⅝ inches high and 2⅜ inches in diameter. They punched a number of holes in the sides to give the volatilized dye a short path through the hot ash, and thus keep the dye from burning. The fuel consisted of sulphur and potassium chlorate, with sodium bicarbonate to absorb some of the heat and keep the temperature down. The ignited grenade emitted a cloud of smoke for approximately 2 minutes. The CWS standardized the munition as the M16 in April 1943, and produced it in 6 colors, red, orange, yellow, green, violet, and black.[48]

After the production of the M16 grenade had gotten underway, the Army Ground Forces studied the performance of the munition in service tests and decided that it would be more useful if the rate of smoke production was increased. It was impossible to raise the volume of smoke by speeding the combustion because a higher temperature would have caused excessive decomposition of the dye. However, the rate of smoke production could be increased by changing the design of the grenade body, the proportion of the ingredients in the mixture, and the pressure under which the mixture was compressed. In the new design, engineers eliminated the side holes and cut one large hole, one-half inch in diameter, down through the middle of the filling. The finished grenade, designated as Model M18, gave off a dense volume of smoke for approximately one minute. The CWS planned to produce eight colors, but later at a conference of Air Forces, Navy, British, and CWS representatives it was

[47] (1) Brig Gen Alden H. Waitt, "Colored Smokes for Protection," *Chemical Warfare Bulletin* 29 (July 1943), 9–10. (2) Ltr, CG AGF to C of Ord, 4 Aug 42, sub: Colored Smoke Grenade. CWS 471.6/211.

[48] (1) S. J. Magram and Leo Finkelstein, Colored Smoke Grenades, M16. TDMR 497, 26 Dec 42. (2) CWTC Item 696, Standardization of Grenade, Smoke, Colored, M16, 23 Apr 43. (3) CWTC Item 749, Approval of Standardization of Grenade, Smoke, Colored, M16, 3 Sep 43.

decided to reduce the number to four contrasting colors, red, yellow, green, and violet.[49]

Colored smoke grenades were employed in every kind of signaling by troops in the field, but the most common use lay in communicating with planes that provided close air support. Planes had to recognize American front lines, artillery positions, and tanks or else they might bomb them accidentally. American forces generally showed yellow smoke to protect themselves from their own planes. Troops found other uses for smoke in marking targets for artillery fire, in communicating with tanks, and in signaling other troops. An indication of the value of colored smoke grenades is the large number, more than five million, produced by the CWS from 1942 to 1945.[50]

Infantrymen found it difficult to throw colored smoke grenades very far. In 1943 upon request of the Army Ground Forces the CWS undertook the development of rifle grenades that could carry several hundred yards. Model M22, the first produced in quantity, was similar in appearance to the M9A1 antitank rifle grenade. It could be sent off by means of the M7 or M8 grenade launcher, from either the M1 rifle or M1 carbine, and upon impact let off colored smoke—red, orange, yellow, green, or violet—for more than one minute. A later model, M23, intended for use in jungle or thick forest where high trees and thick underbrush would hide smoke from hand grenades, released a stream of colored smoke as it arched across the sky. It remained in flight about eleven seconds, reaching an altitude of five hundred feet. Four colors were produced: red, yellow, green, and violet. Filling plants loaded more than one-half million of the impact and the streamer grenades in 1944 and 1945.[51]

The difficulties the CWS faced in finding suitable smoke mixtures for grenades were duplicated in the work on colored artillery shells, mortar shells, rockets, and bombs. Chemists had to formulate mixtures that would release smoke of the desired density for the required time, and engineers had to cope with mechanical obstacles that appeared in casings. Artillery shells posed no unusual problem. Technicians took a base-ejection shell

[49] (1) CWTC Item 797, Standardization of Grenade, Smoke, Colored, M18, 3 Sep 43. (2) CWTC Item 1000, Classification of Fillings for Grenade, Smoke, Colored, M18, 5 May 44. (3) CWTC Item 1637, Cancellation of Blue, Black, White, and Orange Fillings for Grenade, Smoke, Colored, M18, 6 Aug 46.

[50] (1) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21. (2) *First United States Army Report of Operations,* pp. 90–91.

[51] (1) CWS Rpt of Production, 1 Jan 40 through 31 Dec 45, pp. 15–16. (2) Finkelstein, Colored Smokes, pp. 53–61.

developed years before and substituted colored smoke canisters (steel tubes filled with smoke mixture) for white smoke canisters. The shell, in flight, ejected and ignited the canisters which then gave off colored smoke. The shell released its canisters several hundred yards from the target, but the canisters continued to fly through the air and fell close to the point where the projectile landed. The service developed several experimental and standard canisters for base-ejection shells of different calibers, but actually produced only those for 105-mm. and 155-mm. shells. These came in red, yellow, green, and violet. More than two million 105-mm. canisters and almost seven hundred thousand 155-mm. canisters passed along the filling lines. Artillery employed these shells widely in Europe and in the Pacific for indicating targets within enemy territory where black or white bursts could have been confused with the usual smoke of battle.[52]

Artillery shells were only one type of marking and signaling ammunition developed by the CWS. For units in the Pacific, engineers devised 2.36-inch colored smoke rockets to mark positions of units or locations of front lines in dense jungle where smoke from hand grenades could be seen not at all or with great difficulty. Rockets of one type smoked upon impact, those of the other type left a trail of smoke as they flew through the air. For the Army Ground Forces the CWS designed colored smoke shells to fit 60-mm. and 81-mm. infantry mortars, and 4.2-inch chemical mortars. The demand for rockets and shells did not materialize, and the CWS closed the projects without getting into production.[53]

Although infantry and artillery made most use of colored smokes, aviators saw the possibility of using signals for communicating with the ground or with other planes. The Navy asked for a 100-pound colored smoke bomb that could be dropped on beaches to identify areas where troops could be landed quickly. The CWS produced experimental models, but then dropped the project when the Navy changed its mind about the need for such bombs. The Army Air Forces requested a smoke missile that could be used in pattern bombing over Europe. In this method of

[52] (1) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21. (2) Wendell P. Munro, Colored Smokes—Development of Smoke Canister, 105-mm., Base Ejection Shell, M84. TDMR 561, 28 May 43. (3) Wendell P. Munro and J. C. Driskell, Colored Smokes—Development of Smoke Canister, 155-mm. Base Ejection Shell, M115 and M116. TDMR 787, Jan 44.

[53] (1) J. J. Jungbauer, The Early Development of 2.36-inch Chemical Rockets. TDMR 850, 22 Jun 44. (2) J. C. Driskell and M. A. Zizmor, Colored Smoke—2.36-inch Rocket, T32 Streamer. TDMR 977, 14 Feb 45. (3) J. C. Driskell and W. K. Ginman, Colored Smokes—Colored Smoke Shell for the 60-mm. Mortar. TDMR 857, 3 Jul 44. (4) J. C. Driskell, 81-mm. Colored Smoke Shell. TCIR 126, 10 May 44. (5) J. C. Driskell and W. K. Ginman, Colored Smokes: Bursting Type, 4.2-inch Chemical Mortar Shell E72. TDMR 923, 9 Nov 44.

bombing, all planes in the formation released their bombs simultaneously upon signal from the lead plane. A colored smoke bomb dropped by the leader appeared to be a feasible means of giving the signal. In 1944 the CWS started work on this bomb. Engineers took the Ordnance M38A2 100-pound practice bomb, and replaced the sand ballast with pellets of colored smoke mixture. When dropped, the bomb left a trail of colored smoke. Since smoke from this first model was too tenuous to be seen clearly by all planes in a flight, engineers placed a tube in the long axis of the bomb and filled the tube with a string of red and yellow smoke grenades. The first grenade ignited when the bomb left the bay, and the other grenades ignited in succession, leaving an easily visible trail in the sky. Before the war was over the CWS produced fillings for several thousand M87 colored smoke streamer bombs.[54]

The German Army, as the American, had a variety of air and ground colored smoke signals. The most common munitions were small candles about two inches in diameter and holding a few ounces of smoke mixture. The candles, for the colors red, green, blue, and violet, produced smoke for about twenty seconds. German forces employed single colors or combinations to send a variety of signals. An orange smoke candle, issued in three sizes, was used only to send distress signals. For artillery signaling, marking, and ranging, the Germans had 7.5-cm. and 10.5-cm. shells with red and blue smoke fillings, fused for either air burst or impact. In the fighting in Europe, German artillery attempted to cross up signals between American planes and troops and cause planes to bomb American-held territory by firing colored smoke shells into the American lines. All in all, the Germans found colored smoke quite as useful as did the Americans.[55]

The Japanese seemed to have favored colored flares fired from grenade dischargers in their signaling; consequently they did not have as large a variety of colored smoke munitions as the Americans or the Germans. The standard candle was a cylindrical can six inches high, two inches in diameter, and containing a few ounces of red, blue, or yellow smoke mixture. Smoke from these candles was not as thick or persistent as American smoke. The Japanese made up for the lack of variety in their signal gre-

[54] (1) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21. (2) J. C. Driskell, W. K. Ginman, and M. A. Zizmor, Colored Smokes—Colored Smoke Trail Bombs E13, E13R1, and E13R2. TDMR 861, 3 Aug 44. (3) CWTC Item 1132, Standardization of Bomb, Smoke, Colored Streamer, M87, 31 Aug 44.

[55] (1) German Chemical Warfare, p. 139. (2) German Chemical Warfare Materiel, pp. I–E, I–F–3, I–O–1 - I–O–8. (3) *First United States Army Report of Operations*, pp. 90–91.

nades, shells, and bombs by the large variety, at least fifteen, of 50-mm. signal flares that could be seen for several miles, day or night.[56]

Colored smoke munitions were of small importance when compared to the CWS's 4.2-inch chemical mortars, mechanical smoke generators, incendiary bombs, toxic agents, gas masks, and other items, but they proved their usefulness in special situations and contributed to the success of American troops throughout the war.

The armed forces made significant advances in the evolution of smoke tactics during the war. Progress resulted largely from the introduction of two new smoke producing devices, the mechanical smoke generator and the airplane spray tank, and the improvement of conventional smoke munitions and agents. The old and new devices gave the army munitions for almost every conceivable type of operation so that smoke as a military tactic became far more valuable than at the start of the conflict.

The subjects of the previous chapters—chemical agents, incendiaries, smokes, chemical mortars, flame throwers, biological agents—were the chief concern of the CWS during the war. They do not, however, represent the entire scientific program. At times the service carried out other investigations. One of these was begun in December 1944 when the Air Forces asked the CWS to develop propellants for the JB-2 flying bomb, the American counterpart of the German "buzz bomb." A group of scientists, headed by Maj. Frederick Bellinger, investigated three systems of liquid propellants: hydrogen peroxide-permanganate, fuming nitric acid-aniline, and mononitromethane-catalyst. The FRED project (after *Fred*erick Bellinger) ended with the successful launching of the JB-2 bomb at Eglin Field.[57] Another unusual project had to do with the production of iron carbonyl, needed by the Signal Corps. The only commercial source then available was the General Aniline and Film Co. plant at Linden, N.J., managed and operated by German aliens. To assure a steady supply of the compound the Defense Plant Corporation tried to develop the process, but proceeded so slowly that Secretary of War Patterson transferred the project to the CWS. The service co-operated with a chemical engineering

[56] Japanese Chemical Warfare.

[57] (1) Ltr, Frederick Bellinger to Hist Off, 18 Dec 57. (2) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes, J. H. Ladd, and J. E. Ross, "Chemical Propellants: The System Hydrogen Peroxide-Permanganate," *Industrial and Engineering Chemistry*, 38 (1946), 160–69. (3) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes, and W. C. Bull, "Chemical Propellants: Corrosion and Stability Studies," *ibid.*, 310–20. (4) F. Bellinger, H. B. Friedman, W. H. Bauer, J. W. Eastes, and S. M. Edmonds, "Chemical Propellants: Analytical Studies and Characteristics of the System Hydrogen Peroxide-Permanganate," *ibid*, 627–30.

firm in producing the product.[58] Another group of projects had to do with researches on insecticides, miticides, and rodenticides. The CWS was represented on the Army Committee on Insect and Rodent Control, established in November 1944, and also co-operated with the OSRD's Committee on Insect and Rodent Control.[59]

In the approximately four years of World War II the CWS carried on far more technical work than during the previous twenty years of peace. But it could have accomplished even more had there been a larger research and development organization at the start of the war. The service tried to overcome its early handicap by spending large amounts of money, but funds could not buy time.

The Chemical Warfare Service came out of the war with the largest technical organization it had ever had. Its leaders, many of whom had grown up with the service, were impressed with the need for maintaining such an organization lest the mistakes of the past be repeated. They did not want to suffer a repetition of the post World War I experience.

[58] Ltr, Brig Gen Clifford L. Sayre, USAR, to Maj Gen R. W. Stephens, 3 Sep 57. CWS 314.7 R & D File.

[59] Leo Finkelstein and C. G. Schmitt, Insecticides, Miticides, and Rodenticides, vol. 19, 7 Dec 49, monograph in series History of Research and Development of the CWS (1 July 1940–31 December 1945).

CHAPTER X

Peacetime Preparation for Supply

After the CWS developed such items as gas masks, incendiaries, flame throwers, and smokes for the armed forces, it turned to the difficult job of trying to procure them. During World War II the relationship between development and procurement was very obvious, for then the manufacturer was constantly presented with changes in drawings and specifications by those responsible for developing and engineering the item. But even before the war the relationship, though not so clearly apparent, was nevertheless maintained.

The unfortunate experience of World War I when the nation was called on to produce a number of munitions for which there were no detailed specifications led Congress, in the National Defense Act of 1920, to provide against another such contingency. A provision of the act was that the Assistant Secretary of War would be responsible not only for current procurement for the Army but also for peacetime industrial mobilization planning.[1] In the fall of 1921 the Assistant Secretary set up in his office a Procurement Division, made up of a current procurement branch and a planning branch. This division supervised the purchase, storage, distribution, and procurement planning activities of the eight supply arms and services, of which the Chemical Warfare Service was one.[2] In an effort to further strengthen the industrial mobilization program an

[1] Later the duties were shifted to the Office of the Under Secretary. For a discussion of this office and its activities see Troyer S. Anderson, History of the Office of the Under Secretary of War (1919–1941). MS reproduced in OCMH, January 1951.

[2] The other arms and services were the Air Corps, Coast Artillery Corps, Corps of Engineers, Medical Department, Ordnance Department, Quartermaster Corps, and Signal Corps.

Army and Navy Munitions Board was established in 1922 and an Army Industrial College in 1924.[3]

Among the duties of the Assistant Secretary of War was the approval of "shopping lists" for the various supply arms and services. On 9 December 1921 the Assistant Secretary approved such a list for the CWS. Included were toxic agents, smoke materials, cloud gas materials, and chemical engineering equipment.[4] Several reviews of the "List of Supplies to be Procured by the Chemical Warfare Service" were made in the various categories in the 1920's and 1930's, but no substantial changes were effected.[5] The Army supply list served a double purpose—it was a partial list of materials required by CWS for manufacture of its requirements and it was also the authorized procurement list of CWS for procurement planning purposes.[6]

The surplus items of World War I served as the basis of a reserve for an emergency in the postwar years. In the fall of 1921 the chiefs of the technical services were directed to draw up plans for retaining supplies and equipment to meet (1) war needs, (2) the requirements of the defense projects of the insular possessions and the Panama Canal Zone, and (3) the peacetime requirements of the Regular Army, the National Guard, and the Organized Reserves.[7] The CWS already had items of equipment like masks, Livens projectors, and Stokes mortars at the Edgewood Depot and at Schofield Barracks in Hawaii. By 1924 the term, "War Reserves," came to be applied to the stock of supplies maintained to meet war requirements and in that year the Congress authorized such stocks for an army of 1,000,000 men. The concept behind War Reserves was to stockpile enough supplies to equip an armed force from the time war started until that industry could start producing war matériel.[8]

A chief objective of the CWS procurement and supply program was to maintain at optimum level those items of the Army supply list for

[3] For a discussion of the background of interwar industrial mobilization planning see R. Elberton Smith, *The Army and Economic Mobilization*. UNITED STATES ARMY IN WORLD WAR II (Washington, 1959), chs. II and IV.

[4] Rpt of CWS, 1921, p. 5.

[5] Specifically these reviews were made in 1923, 1924, and 1931. The revised lists of 1923 and 1924 are in CWS 400.123 file, National Archives and of 1931 in CWS 381 file, National Archives. AR 50-5 (20 Jul 25) made mention of the procurement list.

[6] Memo, Dir of Proc OASW for C CWS, 5 Nov 24, sub: Procurement Lists. CWS 400.12/78.

[7] Ltr, TAG for C CWS, *et al.*, 13 Oct 21, sub: Computation of War Requirements and the Determination of Surplus. AG 381.4 (3.30.22), Plng Div ASF.

[8] (1) Ltr, TAG to ASW, *et al.*, 23 Jan 33, sub: War Reserves. AG 381.4 (10-31-32) (Misc) M-D, Plng Div ASF, War Reserves, 1934. (2) Memo for Record on War Reserves, Col James H. Burns, 7 Oct 38. Plng Div ASF, War Reserves, 1935-38.

which the CWS had procurement responsibility. The service never attained this objective because of the low appropriations for CWS procurement. In 1926 the Assistant Chief of Staff, G-4, reported deficits in all items stored and issued by the CWS in the War Reserves.[9] These items included the following: gas masks, canisters, charcoal, phosphorus, Stokes mortars, Livens projectors, portable cylinders, smoke candles, lachrymatory candles, Livens projector smoke shells, Livens projector incendiary shells, 4-inch Stokes mortar chemical shells, and 4-inch Stokes mortar smoke shells. Planners then estimated that it would require $3,737,741 to bring the War Reserves up to the million-man requirement.[10] They figured that for critical chemical warfare items it would take twenty-two and one-half million dollars to build up War Reserves for a million men. Critical chemical warfare items were those indispensable munitions which could not be procured in time to meet the initial requirement of mobilization. They were listed in 1937 according to three priorities. Included under the first priority were the various chemical agents, 4.2-inch mortars and ammunition, impregnite, masks, collective protectors, and airplane spray tanks. The second priority consisted of gas alarms, irritant candles, Livens projector shells (less chemical filling), portable chemical cylinders, field laboratories, Livens projector accessory sets, and wrenches for portable chemical cylinders. Under the third priority came CN (tear gas) capsules, 8-inch combination pliers, colored drawing sets for chemical warfare material, gas identification sets, and CWS insignia stencils.[11] The experience of the CWS was similar in this respect to that of the War Department as a whole. Col. James H. Burns, of the Office of the Assistant Secretary of War, estimated in 1938 that there was a shortage in the War Reserves of $507,000,000 just in critical items using standard equipment.[12]

Another objective of the procurement and supply program in the CWS was to fill the peacetime requirements of the Regular Army, the National Guard, the Organized Reserves, and, upon request, the Navy. The gas mask was the principal item of issue, although some munitions such as grenades and nontoxic drop bombs were manufactured and issued chiefly for training purposes.[13]

[9] Memo, C Supply Br G-4 for ACofS G-4, 25 Jan 26, sub: War Reserves Stored and Issued by CWS. G-4/13765.

[10] *Ibid.*

[11] Critical Items, sec. II, 1 Dec 37, Incl 8 to Ltr, TAG to ASW, *et al.,* 17 Dec 37, sub: War Reserves. AG 381.4 (11-8-37) (Misc)-D, CWS 314.7 Supply File.

[12] Memo for Record on War Reserves, Col James H. Burns, 7 Oct 38. Plng Div ASF, War Reserves, 1935-38.

[13] Rpt of CWS, 1928, p. 12.

The Supply Division (later the Manufacturing and Supply Division) in the chief's office had general supervision over all CWS procurement and supply. Actual manufacture and procurement as well as storage and issue was carried out almost exclusively at Edgewood Arsenal. There the gas mask factory turned out masks for the Army and the Navy and there some of the filling plans occasionally came out of hibernation to grind out the few munitions required for training. The depot at Edgewood stocked War Reserves and items of current issue and filled requisitions coming in from the continental United States and the overseas departments. At the Edgewood Depot were also stored the surplus toxics from World War I, over which constant surveillance was mandatory.

The chief item of manufacture, as just mentioned, was the gas mask. The production program of 1920-21 [14] was followed by a drastic reduction in the years 1922 to 1926, when only 900 masks were manufactured for the Army.[15] During the same period, however, a good many masks were made for the Navy, the Marine Corps, and the United States Public Health Service. Production in modest volume for all users continued from 1927 to 1938. (*Table 3*)

TABLE 3—GAS MASK PRODUCTION AT EDGEWOOD ARSENAL, 1927–1938

Year	Number of Masks	Year	Number of Masks
1927	23, 560	1933	16, 235
1928	24, 667	1934	31, 564
1929	27, 000	1935	25, 785
1930	42, 180	1936	41, 700
1931	23, 208	1937	51, 167
1932	20, 904	1938	18, 734

Source: Ltr, Arsenal Operations, Edgewood Arsenal, Cml Warfare Center, Md., to Hist Br OC CWS, 4 Sep 45, sub: Edgewood Production. CWS 314.7 Edgewood Arsenal File.

The continued manufacture of masks at the Edgewood factory enabled the CWS to keep alive a highly technical art until such time as private industry could get into production. Not only did factory managers and supervisors gain valuable experience, but the skilled and semiskilled workers of the Edgewood gas mask plant were able to train workers in private plants in the period of emergency preceding World War II. This situation was in marked contrast to the lack of experienced supervisors and

[14] See ch. I.

[15] These 900 were made in 1925 for special field tests of the diaphragm facepiece by the using service. Memo, C CWS for ACofS G-3, 29 Nov 26, sub: Functions of the Chemical Warfare Service. In OC CWS "black book" on policy.

workers in such operations as the manufacture of toxics, smokes, and incendiaries. The emergency forced the service to call to active duty a number of reserve officers with experience in private industry to supervise the technical operations of its arsenals and plants which produced these munitions.

Planning for Mobilization

The CWS, like the other technical services of the Army, was consulted in the formulation of the general Industrial Mobilization Plan and was also assigned planning responsibility for specific items designated by the Assistant Secretary of War. These were the items included on the "List of Supplies to be Procured by the CWS," as already indicated. To carry out the procurement planning activities, an Industrial Relations Division was set up in OC CWS in 1920. This division was renamed the Industrial War Plans Division in 1925 and in 1926 the Procurement Planning Division, a designation retained until 1940.[16] In January 1924 five procurement district offices were opened in the following cities to carry out procurement planning activities: New York, Boston, Pittsburgh, Chicago, and San Francisco.[17] Edgewood Arsenal, in addition to its actual peacetime procurement and manufacture, also engaged in industrial mobilization planning.

From 1937 onward all industrial mobilization planning was based on the manpower requirements of the Protective Mobilization Plan (PMP). The PMP called for an army of 400,000, within 30 days after mobilization, known as the Initial Protective Force and made up of the Regular Army and the National Guard. Within 4 months, the number would be raised to 1,000,000 men and within 14 months to a peak wartime figure of 4,000,000. The CWS planned for both units and facilities under the PMP and estimated the time it would require to furnish the mobilized forces with critical and essential items, such as gas masks, toxic agents, smoke, munitions, impregnite, airplane spray tanks, and shells for 4.2-inch chemical mortars.[18]

[16] (1) OC CWS Orgn Chart, 7 Nov 20. (2) Rpt of CWS 1925, p. 26. (3) Rpt of CWS, 1926, p. 25.

[17] Brophy and Fisher, *Organizing for War*, ch. II.

[18] (1) Ltr, ACofS G-4 to C CWS, 1 Oct 36, sub: Manufacture and Supply of Essential Chemical Agents. G-4/29895. (2) Memo, ACofS G-4 for C CWS, 20 Jun 38, sub: CWS Program for National Defense. G-4/29895-1. (3) Ltr, C CWS to TAG, 13 Jul 37, sub: The Protective Mobilization, Plan, and 1st Ind, C CWS 28 Dec 37, on Ltr, CmlO 3d Corps Area, 22 Dec 37, sub: Critical Items, CWS. Both in CWS 381/259, pt. 1, Jan 37 thru Dec 38. (4) Ltr, C CWS to TAG, 13 Jul 39, sub: Supply Facilities under the P.M.P. 1939. CWS 381/259, pt. 2, Jan 39 thru Dec 39.

Procurement Planning

Planning for the procurement of matériel was but one phase of the industrial mobilization process.[19] Because it was relatively inexpensive the CWS concentrated on this activity more than on other aspects of industrial mobilization.

Procurement planning involved the following steps by CWS:

1. The computation of the quantities and time of delivery as required under the War Department Mobilization Plans.
2. The preparation of specifications for each item to be bought or manufactured.
3. The decision as to what matériel should be manufactured by government plants and what should be obtained from industry.
4. The preparation for the procurement of such matériel. Although the CWS was responsible for the spade work involved, all proposals had to meet with the approval of the General Staff and of the Assistant Secretary of War.[20]

Computation of Requirements

The computation of requirements through most of the period was a relatively simple process because the basis of calculation was the number of individuals or units that were to be supplied with defensive items of equipment. Offensive munitions were not taken into consideration until the late thirties; the color plans [21] made no provision whatever for the use of toxics, although the YELLOW plan called for dispatching four companies of CWS troops and a large quantity of tear gas with the expeditionary forces.[22] The Procurement Planning Division of the chief's office

[19] The CWS Annex to the 1925 Industrial Mobilization Plan listed the following activities that would have to be carried out in peacetime as a basis for wartime expansion:

1. Maintenance of present manufacturing facilities.
2. Maintenance of a war reserve.
3. Research, development, and proving.
4. Small-scale manufacture.
5. Procurement planning.

War Plan for Industrial Mobilization, Annex 7, CWS, 5 Feb 25, submitted by C CWS to ASW, 5 Feb 25. CWS 400.123/141.

[20] For a discussion of procurement planning in the War Department see Smith, *The Army and Economic Mobilization*, ch. III.

[21] For color plans see (1) Maurice Matloff and Edwin M. Snell, *Strategic Planning for Coalition Warfare, 1941–1942* (Washington, 1953), p. 6 and (2) Mark Skinner Watson, *The Chief of Staff: Prewar Plans and Preparations* (Washington, 1950), pp. 87–89, both in UNITED STATES ARMY IN WORLD WAR II.

[22] Memo, ACofS G-3 for CofS, 28 Mar 27, sub: CWS Functions, G-3/5749.

prepared tables of equipment and tables of basic allowances as well as distribution and maintenance factors. These it defended before the Planning Branch of the Office of the Assistant Secretary of War. The Procurement Planning Division also computed the quantities of chemical warfare items and components which would be required by the Army and Navy during the 14-month period of mobilization.

Until the mid-thirties there was little correlation between the manpower requirements of the War Department general mobilization plans and the industrial mobilization plans. The general mobilization plans of the early twenties had called for six and one-half million men, a figure which was reduced to less than four million men in the 1933 plan.[23] For a number of years planners gave little concern to equipping this huge force, because of the existence of surplus items remaining from World War I. By the early thirties this World War I equipment had become obsolete and the War Department had to give more serious consideration both to procuring sufficient War Reserve matériel and to drawing up more realistic plans for procurement in an emergency.

The 1930's saw a marked revision in mobilization planning. The Assistant Secretary of War, who later became the Secretary of War, Harry H. Woodring, and the Chiefs of Staff, Generals Douglas MacArthur and Malin Craig, worked together to make the plans more realistic. The result was the Protective Mobilization Plan of the late 1930's which called for the gradual mobilization of an army of four million men over a 14-month period and the gearing of procurement planning to the new concept.[24]

Preparation of Specifications

A second step in procurement planning was the preparation of specifications for the item to be procured. The specification described the item in detail, listed the materials and other information required for its manufacture, and outlined the methods to be employed in its inspection and

[23] (1) Memo, ACofS WPD for CofS, 21 Sep 21, sub: Determination of a Basis for the Further Declaration of Surplus Supplies. AG 318.14, (3.30.22), Plng Div ASF. (2) Watson, *The Chief of Staff: Prewar Plans and Preparations*, pp. 23–31. (3) Marvin A. Kriedberg and Merton G. Henry, *History of Military Mobilization in the United States Army, 1775–1945*, DA Pamphlet No. 20-212, June 1955, chs. XII and XIII.

[24] (1) *Annual Rpt SW, 1938*, p. 1. (2) Otto L. Nelson, *National Security and the General Staff* (Washington: The Infantry Journal Press, 1946), pp. 303–04. (3) Watson, *The Chief of Staff: Prewar Plans and Preparations*, pp. 26–31. (4) Kriedberg and Henry, *History of Military Mobilization in the United States Army, 1775–1945*, chs. XIV and XV.

testing. The CWS, unlike the older technical services, had to start almost from scratch in developing a complete set of specifications, because its experience was limited to World War I. The items for which the CWS drew up specifications were generally those included on the supply list.[25]

The actual writing of the specifications was done by the Technical Division at Edgewood Arsenal. All specifications were reviewed by a board made up of representatives of the Technical, Production, and Inspection Divisions of the arsenal. After the board had made a preliminary review of the specifications, the chief's office sent them through the procurement district office to industrial firms experienced in the manufacture of the item. Final approval had to come from the Standards Division, Office of the Assistant Secretary of War.[26]

In spite of the fact that the CWS wrote specifications for a great many items, a considerable part of its labor, unfortunately, went for naught, because many specifications were found not suitable once the items were put into production during the emergency or early war period. One feature of the specification of the gas mask, for example, was a requirement for brass. While there were definite advantages in the use of this metal, brass was simply not to be obtained when war came and substitutes had to be found. A more serious defect was that the specifications for some items were written on the basis of experience with models fabricated by hand at the lone machine shop at Edgewood Arsenal, a method which gave little indication of the mass producibility of the items. Surprisingly, the industrial concerns which reviewed the specifications did not point out this fact. It must be borne in mind, however, that the manufacturers were requested to do this work gratis and as a result their reviews were often not as thorough as they might have been. Only when the period of the emergency brought the prospect of actual contracts did the review of specifications by industry prove truly valuable. The ideal procedure, in the opinion of several CWS officers who had experience with the handling of specifications, would have been to award contracts to engineering firms specializing in such work. But since no funds were allowed for thus purpose such a procedure was not possible.[27]

[25] Copies of all CWS specifications are filed at Chemical Corps Engineering Command, ACmlC, Md.

[26] Smith, *The Army and Economic Mobilization,* pp. 50–51.

[27] Intervs, Hist Off with Col Harry A. Kuhn, USA Ret, 19 Oct 53; Lt Col Rura O. Ball, 1 Oct 53; and H. C. Fischer, Supt, Machine Shop, ACmlC, 8 Oct 53. Colonel Kuhn had experience in procurement planning in NYCWPD and Colonel Ball at the War Plans Division EA and in the OC CWS.

Government Plants or Private Industry?

The procurement experience of the CWS in World War I had a definite influence on procurement planning in the postwar years. During that war chemical warfare items were obtained through manufacture in both government plants and private industry. The chemical industry never waxed enthusiastic about manufacturing toxic agents. After the war it became an accepted Army policy that the production of these agents was "attended with so many hazards" that their manufacture should be restricted to government arsenals and plants.[28] These same government installations would also manufacture smokes, incendiaries, and nontoxic gases, and would fill the required shells, bombs, and grenades. The raw materials and chemicals as well as the chemical engineering equipment needed for this manufacture would be purchased through the procurement districts. Gas masks would be procured both from private industry and from government factories.[29]

In the 1920's the CWS believed that the facilities at Edgewood Arsenal could fill the requirements for smoke, incendiaries, and toxic and non-toxic agents during the first eight months of an emergency, by which time a second arsenal in the vicinity of Memphis, Tenn., could be erected to help carry the production load.[30] These plans were made in the years when the manufacturing and filling plants at Edgewood were not yet beyond hope of rehabilitation. The Edgewood facilities were not restored, as already noted, and by the close of the 1920's most of them were ready for the scrap heap.

With the appointment in 1933 of Mr. Woodring as Assistant Secretary of War and Maj. Gen. Claude E. Brigham as Chief, CWS, more stress was placed on planning for the procurement of items of chemical ammunition, their components, intermediate and raw chemicals, and on arsenal planning.[31] The first tangible result of the emphasis on arsenal planning was the creation of a War Plans Division at Edgewood Arsenal in the fall of 1934. This division was staffed by an officer or two and a few civilian engineers and draftsmen. Its function was to draw up plans

[28] Memo, ACofS G-4 for CofS, 25 Mar 25, sub: Necessary Peacetime Preparation to Insure Successful Opposition to an Enemy Using Chemical Methods of Warfare. AG 321.94 (3-25-25) (1).

[29] CWS Gen Mob Plan based on WD Gen Mob Plan, 1928, pp. 8-9.

[30] (1) War Plan for Ind Mob, an. 7, CWS, 5 Feb 25, p. 5. CWS 400.123/141. (2) CWS Gen Mob Plan based on WD Gen Mob Plan, 1928, p. 8.

[31] Rpt of CWS, 1934, p. 3.

for rehabilitating old arsenal plants or building new ones, "capable of meeting average monthly requirements of Section 11-A, P.M.P."[32] For a time the division was under the general supervision of the technical director at Edgewood, but in July 1936 it was placed directly under the jurisdiction of the commanding officer at Edgewood Arsenal.[33] While the War Plans Division assumed chief responsibility for arsenal planning, it was not the only agency in the CWS carrying out such activity. The Engineering Division at Edgewood drew up certain plans for which its members had special qualifications, such as those for a phosgene filling plant and an impregnite (CC-2) plant. These plans were to prove valuable when construction of new facilities was undertaken in the emergency period.[34]

LT. COL. CLAUDE E. BRIGHAM *(photograph taken before 1932 when Brigham became a general officer).*

While the planners were studiously drawing up their blueprints, the Chief, CWS, was losing no opportunity of calling the attention of the Chief of Staff to shortages that would exist on M-day, unless some actual rehabilitation or new construction were undertaken. In the summer of 1934 General Brigham notified the Chief of Staff that it would take from four to nine months to put the manufacturing and filling plants into operation and he urged that they be partially rehabilitated as soon as possible.[35] General Brigham's estimate of the situation was generally confirmed by a study made in the fall of 1936 by the Planning Branch of the Office of the Assistant Secretary of War on procurement possibilities under the 1933 Mobilization Plan. That study included two chemical warfare items, the

[32] Report of Activities of Edgewood Arsenal for the month of Jan 1938, pt. X, WPD. CWS 319.1/2183-2249. 1936-41.
[33] EA GO 4, 1 Jul 36.
[34] Rpt on Arsenal Planning Proj, CO EA to C CWS, 4 Mar 36. CWS 322.095/727.
[35] Memo, C CWS for CofS, 31 Aug 34, sub: Major Deficiencies in CWS. CWS 679/5.

gas mask and mustard gas. It concluded that for neither of these would the supply requirement be met until ten months after M-day.[36]

In order to improve the preparedness status of the service the Chief, CWS, in the spring of 1936 suggested to the Chief of Staff that a 5-year program be undertaken in the CWS.[37] This program would cover all phases of the CWS mission, including research and development, training, procurement, and supply. The procurement phase of the program included the erection of new facilities for the manufacture of important reserve material, which the Chief, CWS, listed in the following order of urgency: impregnite, gas masks, persistent gas, nonpersistent gas, ammunition for chemical weapons, and collective protectors. General Brigham estimated the cost of the projected CWS program for the years 1938–42 as follows:

1938—$4,331,879
1939— 4,294,307
1940— 5,791,819
1941— 5,737,669
1942— 5,122,669

General Brigham's recommendations were no doubt prompted in part by the action of the Joint Board in the summer of 1935 in confirming CWS responsibility for research and procurement of chemical warfare matériel for the Army, the Navy, and the Marine Corps.[38]

The Chief of Staff referred General Brigham's suggestion to G–4 for study and comment. The Chemical Warfare program was, of course, only one of a number which the General Staff was called on to evaluate, and the amount of funds which the Bureau of the Budget would approve for military purposes at that time was strictly limited.[39] The War Department General Staff, therefore, had to closely scrutinize all programs entailing an expenditure of funds. To complicate matters still more, both G–4 and the Office of the Assistant Secretary of War had definite misgivings about spending too much money on chemical plants which they felt might become obsolete in a few years. Their attitude was reflected in the words of the director of the Planning Branch of the Office of the Assistant Secre-

[36] OASW, Procurement Possibilities Under the 1933 Mobilization Plan, October 1936.

[37] Memo, C CWS for CofS, 21 Mar 36, sub: National Defense Against Chemicals. CWS 381/125–154.

[38] (1) Ltr, Sr Member, Jt Bd to SW, 21 Aug 35, sub: Chemical Warfare. Jt Bd No 330, Ser 550. (2) For a discussion of CWS relations with the Navy, see Brophy and Fisher, *Organizing for War*, ch. III.

[39] (1) Nelson, *National Security and the General Staff*, p. 307. (2) Watson, *The Chief of Staff: Prewar Plans and Preparations*, p. 48.

tary of War, commenting approvingly on a G-4 study of 1936: "I believe," he said, "Edgewood Arsenal should be rehabilitated only to the extent previously recommended by this office, i.e., the smallest most up-to-date commercially reproducible unit, but that each type of equipment should be properly housed and made shipshape." [40] Assistant Secretary Woodring expressed himself in the same vein when after a vist to Edgewood Arsenal in May 1936 he sent the following note to the Chief of Staff, General Malin Craig:

> As a result of our recent visit to Edgewood Arsenal, I am not favorably impressed with the idea of rehabilitating the Chemical Warfare manufacturing plant. It would seem advisable to have more manufacturing work done by commercial plants and utilize funds to become available for the Edgewood Arsenal for experimental and developmental projects. The question of secrecy in manufacturing processes may have some effect on outside manufacture but should not prevent it.[41]

It is understandable, then, why G-4 did not give favorable consideration to General Brigham's suggestions.[42] Instead of the annual expenditure of about 5 million dollars which the Chief, CWS, had proposed, G-4 recommended a total expenditure of a little over 6 million dollars for the entire five-year period.[43] This G-4 estimate was to be drastically revised after the German invasion of Poland in September 1939. With the funds actually allotted in the late 1930's the CWS built and operated small production units for toxic agents, impregnite, and white phosphorous at Edgewood Arsenal.

Planning for the Gas Mask

On no other item was there more planning than on the gas mask. Although masks were manufactured in peacetime at Edgewood Arsenal, plans called for procuring masks at various points throughout the country in the event of an emergency. The plans of the twenties and early thirties specified that the Edgewood plant would run at full capacity during the first few months of a war until government assembly plants in various cities throughout the country, such as Philadelphia, Pittsburgh, St. Louis, Memphis, and Los Angeles, would be in operation. The gas mask factory at Edgewood would then be discontinued. While the government plants

[40] Memo, Dir Pl Br OASW for The Ex OASW, 27 Aug 36. G-4/29895.

[41] Memo, ASW for Gen Craig, 25 May 36, sub: Rehabilitation of Edgewood Arsenal. Plng Div ASF, Arsenal Reserve Plants-CWS.

[42] The General Staff and the OASW co-operated closely on decisions regarding procurement planning. See Smith, *The Army and Economic Mobilization,* ch. III, and Nelson, *National Security and the General Staff,* p. 304.

[43] Memo, ACofS G-4 for CofS, 20 Jun 38, sub: CWS Program. G-4/29895-1.

would do the actual assembling of the masks, private contractors would supply the components.

The plans for the purchase of these components were worked out in considerable detail in the various procurement district offices before being submitted to the Procurement Planning Division, OC CWS. The district office plans were not confined to the components of the mask, but they were of primary concern while chemicals were secondary. Each procurement district was headed by a civilian chief, who was chairman of an advisory board of five to ten members drawn from among the leaders of the community in the fields of science, commerce, and industry. Each district also had a military executive officer, usually of company grade, with a civilian assistant. The planning activities of the district office were facilitated by the assignment of selected CWS Reserve officers to appropriate mobilization duties. From the ranks of these Reserve officers were to come competent officer material for World War II.[44]

In accomplishing their procurement planning mission, the district offices conducted surveys to determine appropriate facilities for manufacturing the items, such as the gas mask and others, apportioned to them by the Assistant Secretary of War. The results of these surveys were reported to the Office of the Assistant Secretary, who thereupon allocated specific facilities to the districts. Representatives from the district offices then approached the management of these allocated facilities with the request that they sign a schedule of production, which was a mutual statement of intention of the contractor to produce the item or items specified in certain quantities and of the government to purchase such material if needed. These schedules of production were in no sense binding contractual obligations. The understanding was, however, that the allocated facilities would devote all, or a specified portion, of their wartime production capacity to the particular supply branch to which they were allocated.

From the mid-thirties on, there was a changed conception in procurement planning for the mask. Both the Assistant Secretary and G–4 believed that more emphasis should be placed on contracting with private industry in the event of an emergency and this attitude was reflected in the plans of the CWS. A CWS arsenal procurement plan of March 1935, for example, called for the Edgewood gas mask plant to work at full capacity until six months after mobilization, whereupon some nine private contractors would assume entire production of the mask. No mention whatever was

[44] Brophy and Fisher, *Organizing for War*, ch. VII.

made of the government assembly plants in various cities, referred to in previous plans.[45]

The increased attention by the Assistant Secretary's Office to meeting the requirements of the 1933 Mobilization Plan led to a greater emphasis on possible shortages in the supply of gas masks. In June 1935 the Chief, CWS, notified G-4 that the existing plant at Edgewood Arsenal, operating twenty-four hours a day, could not meet the requirements of the 1933 plan, and recommended corrective action. "The choke point in meeting requirements, by the use of additional manufacturing plants," the Chief said, "is the lack of special gauges, dies and jigs, and other apparatus not commercially available. The National Defense Act authorizes the procurement of these items in times of peace, but no funds have been appropriated for this purpose." [46] General Brigham urged that provision be made in the budget estimates for the fiscal year 1937 for buying the necessary gauges, dies, and jigs. The request was honored and $25,000 was appropriated for this purpose in the fiscal year 1937 and a similar sum for the following fiscal year.[47] These sums were not large, but they did enable the CWS to be in a fair position, so far as tooling went, when the time came for actually producing more masks.

General Brigham, as early as January 1936, believed that the time had come for manufacturing masks in greater numbers. He suggested to the Chief of Staff that a 5-year program aimed at procuring 100,000 masks each year be initiated.[48] This suggestion, though approved in principle by the General Staff, was never implemented because of inadequate appropriations. Procurement of masks on a considerable scale was to wait until the enactment of educational order legislation by Congress on 16 June 1938.[49] Immediately upon the enactment of this legislation the Secretary of War appointed a board of officers from the technical services, the War Department General Staff, and the Office of the Assistant Secretary of War

[45] Arsenal Procurement Policy CWS, 15 Mar 35, an incl to Ltr, C CWS to Dir Pl Br OASW, 9 May 35, same sub. Plng Div ASF, Arsenal Reserve Plants-CWS.

[46] Memo, Actg ACofS G-4 for CofS, 14 Jun 35, sub: Budget Estimates CWS for FY 1937. G-4/30376.

[47] (1) Ltr, C CWS to CofS, 19 May 37, sub: Final Report on the Status of Chemical Readiness by the Retiring Chief, CWS, and Memo (Draft) C CWS for ACofS G-4, 30 Apr 38, sub: Data Collected for Use in Connection With the Preparation of a Program for the CWS. Both in G-4/29895-1. (2) Interv, Hist Off with Lt Col Rura O. Ball, 16 Mar 51. Colonel Ball was with War Plans Div, EA, from November 1938 till after outbreak of the war.

[48] Memo for ACofS G-4, 30 Apr 38.

[49] (1) P.L. 639, 75th Cong. (2) In *Annual Rpt of SW, 1931,* p. 157, an educational order is defined as "a contract placed, without advertising, for a limited quantity of a desired technical article, with any selected facility."

to select items for the first orders under the program. The CWS was represented on this board by Maj. George F. Unmacht. The board selected six items, one of which was the gas mask.[50]

Viewed in retrospect and with all the advantages of hindsight it is possible to point out several miscalculations in the prewar mobilization planning of the CWS. The first was the assumption that there would be an orderly transition from peace to war. A second was the failure to realize the global extent of the coming war. These two concepts generally characterized the thinking of the planners throughout the War Department. In addition there were two other basic miscalculations in chemical warfare planning. One was the conviction that gas warfare was all but inevitable and the other was the failure to draw up procurement plans for what turned out to be the most important chemical warfare items to be used in World War II—incendiary bombs, high explosive mortar shells, flame throwers, and smoke generators. The oversight, so far as incendiary bombs and high explosives were concerned, resulted from uncertainty over the CWS mission.[51] With regard to flame throwers and smoke generators, the CWS planners failed to draw up procurement plans because development of those munitions was not emphasized in the period of peace.

The procurement and supply activities of the two decades following World War I reflected the diplomatic and economic developments of the period. The efforts of the United States Government to disarm, and to eliminate war as an instrument of national policy, together with the advent of the greatest depression in the nation's history, militated against a strong military preparedness posture, particularly in the field of chemical warfare. Until the late 1930's little money was expended for CWS procurement or construction, although a great deal of time and effort went into the planning of these activities.

Hopes for world peace, so buoyant in the 1920's, were dashed against the realities of international lawlessness in the 1930's when Japan invaded Manchuria and China and when the armies of Mussolini invaded Ethiopia. These act were followed in September 1939 by the march of Hitler's forces into Poland. With these developments came a gradual change in the attitude of the government on military preparedness. The closing years of the decade were to see not only a greater emphasis on planning, but the initiation of programs to implement the plans.

[50] Rpt of CWS, 1939, p. 17.
[51] Brophy and Fisher, *Organizing for War*, ch. III.

CHAPTER XI

Beginnings of Industrial Mobilization

The years 1939–41 were a period of initial industrial mobilization, during which programs for the construction of badly needed facilities got under way and a start was made in procuring critical and essential items. This period was to reap the reward of the labors of the previous years, when so many blueprints for arsenals and plants had been drawn up and so many procurement plans had been made in the Chemical Warfare Service.

Although the President did not put the Industrial Mobilization Plan of 1939 into operation, the plan was nevertheless followed rather closely in War Department procurement activities for the Army at large.[1] So far as the CWS was concerned, it had a much more restricted application. In the general scramble for contracts by all elements of the armed forces and by foreign governments after the outbreak of war in Europe in 1939, many allocated plants were lost to the CWS. In only one chemical warfare procurement district, New York, were contracts awarded on a considerable scale to previously allocated manufacturers.[2] This situation was probably due to the fact that the majority of the contracts in the New York district were for certain raw chemicals for which there was no keen competition. In other districts, it was the exception rather than the rule for a previously allocated plant to be awarded a contract.[3]

[1] (1) Industrial College Armed Forces (ICAF), R63, Use of Industrial Mobilization Plan in World War II, April 1945, pp. 1–5. ICAF Library. (2) Smith, *The Army and Economic Mobilization,* pp. 83–86.

[2] Interv, Hist Off with Col Harry A. Kuhn, 19 Oct 53. Kuhn was chief of the New York district in the early part of the war.

[3] (1) Intervs, Hist Off with following procurement district officers of WW II: Col Raymond L. Abel, 23 Apr 55; Col Victor C. Searle, 18 Apr 55; and Walter E. Spicer, Jr., 28 Apr 55. (2) ICAF R63, Use of Industrial Mobilization Plan in World War II. See especially Table 1.

Procurement planning in the emergency period took on a new sense of urgency because of the immediate need to supply a progressively growing army with the implements of war. The initiation of the building and procurement programs affected the nature of procurement planning, for considerable attention had to be paid to such matters as priorities and the availability of machine tools. While such matters were of primary concern to those then engaged in construction and procurement operations, they were also of vital interest to the procurement planners.

Educational Order Program

After the enactment of educational order legislation on 18 June 1938 and the selection of the gas mask as one of the six Army items to be procured, the Assistant Secretary of War called upon the Chief, CWS, for a suggested 5-year educational order program for his service to include items and facilities to be procured, the order of priority, and the amount of funds to cover each item.[4] In reply the Chief, CWS, listed the following gas mask items and facilities in the order of priority. For fiscal year 1939, Number 1 priority was the procurement and installation of all equipment required for assembling the complete standardized service gas masks at a rate of 100,000 per month; Number 2, the procurement of equipment for manufacturing impregnated charcoal at the rate of 4,000 pounds per day; Number 3, the procurement of required metal components for the canister; Number 4, the procurement of manufacturing aids such as molds, dies, jigs, and gauges; and Number 5, the procurement of additional components. Under the first three priorities, specific manufacturers were recommended for contracts. For the fiscal year 1940 the Chief, CWS, recommended substantially the same priorities as those for fiscal 1939. For the fiscal years 1941–1943 inclusive the CWS planned only comparatively minor activities, such as retesting of equipment by contractors. Because of the outbreak of the war, the educational order program lasted not five years, but only about half that period. During that time it was to follow rather closely the lines proposed by the Chief, CWS, to the Secretary of War in the summer of 1938.

The fact was that the planners in the CWS had been discussing the educational order programs for a number of years and had well formulated ideas by the time the legislation was finally enacted.[5] Those manufactur-

[4] Ltr, ASW to C CWS, 20 Jun 38, sub: Program Under Educational Order Legislation. CWS 011–21.

[5] Ltr, ExO OC CWS to CO EA, 22 Sep 38, sub: Educational Orders. CWS 011–21.

ers whom the Chief, CWS, recommended for contracts were well known to CWS procurement planners as well as to the research and development personnel, for there had been constant contact with industry with regard to the improvement of the mask. An example of benefit deriving from such contact was the case of the fully molded facepiece. In the 1930's the government scientists at Edgewood were doing a great deal of work on improving the facepiece of the mask and eventually a new and better faceblank was devised consisting of a single piece of molded rubber.[6] While this faceblank was still in the development stage, the CWS considered the feasibility of mass producing the item. It approached a number of rubber manufacturers who for a time showed an interest in the problem. But after a couple of years the general reaction was one of discouragement among both the industrialists and CWS planners.[7] Only two manufacturers, the Acushnet Process Co. of New Bedford, Mass., and the General Tire and Rubber Co. of Akron, Ohio, remained hopeful. One CWS officer in close touch with the problem, Maj. Charles E. Loucks, technical director at Edgewood, shared their optimism and gave them all possible encouragement. The reward came when P. E. Young, president of the Acushnet Process Co., through his own personal research and experimentation, demonstrated that fully molded face blanks could be produced in mass, a conclusion which the General Tire and Rubber Co. arrived at independently.[8] Through such contacts as these the CWS increased its knowledge of the capabilities of the various prospective gas mask contractors.

Under educational order legislation, bids were received only from those firms that had been selected by the Secretary of War and any contract entered into as a result of the invitation to bid had to be approved by the President of the United States. Usually, although not always, the Secretary of War solicited bids from the firms recommended by the CWS.

The first educational order of the CWS went to the Goodyear Tire and Rubber Co. for the operation of a service gas mask assembly plant at Akron, Ohio. This contract, the only CWS educational order contract written in fiscal year 1939, resembled all later contracts in requiring the

[6] The patent on this fully molded facepiece, U.S. Pat. 2,164,330, 4 Jul 39, was awarded to Sidney H. Katz and D. O. Burger.

[7] Ltr, Dewey and Almy Chemical Co to Lt Col A. M. Prentiss, 20 Aug 37, and 1st Ind. In Corres files, CW Labs, A CmlC, Md.

[8] (1) Ltr, P. E. Young to Hist Off, 15 Apr 52. (2) Ltr, P. E. Young, Acushnet Process Co, to C CWS, 27 Oct 37. In Corres files, CW Labs, A CmlC, Md.

actual manufacture of a specified number of items in connection with the contract, in this instance 3,000 masks. In fiscal 1940 the CWS awarded two other contracts for service gas mask assembly plants, one to the Firestone Rubber and Latex Products Co. of Fall River, Mass., and the other to Johnson and Johnson at its Chicago plant. The same year also saw the following additional awards:

1. Construction of a gas mask carrier line at the Goodyear Tire and Rubber Co. plant in Akron, Ohio.

2. Construction of charcoal and whetlerite plants by Barnebey-Cheney Brothers Engineering Co. at Columbus, Ohio, and Carlisle Lumber Co. at Onalaska, Wash.

3. Erection of a complete canister component manufacturing plant at the Milwaukee Stamping Co. in Milwaukee, Wis.

4. Construction of plants at Akron, Ohio, and New Bedford, Mass., for the manufacture of faceblanks.

5. Construction of five noncombatant gas mask assembly plants at various points throughout the country.

6. Erection of an impregnite (CC-2) plant at Niagara Falls, N.Y.

Although educational order contracts were awarded mostly for gas masks and components, one contract was written in fiscal 1940 for a CC-2 plant. In the following fiscal year the CWS awarded educational order contracts for the construction of a shoe impregnite plant and for the manufacture of filter paper. (*Tables 4 and 5*) [9]

The educational order program in the CWS proved invaluable in supplying much needed facilities and in enabling the representatives of the government and industry to co-operate in solving manufacturing and other problems. At the time the program was initiated the Chief, CWS, delegated responsibility for its administration to the chief of the Manufacturing and Supply Division of his office. At the same time he directed that an additional officer of company grade be assigned to the War Plans Division at Edgewood Arsenal to assist in the administration of the program. This procedure was followed throughout the life of the contracts.

The Munitions Program

If the educational order program permitted the CWS to take the first faltering step in an accelerated procurement program in the emergency

[9] AG Memo for Record on CWS Educational Order Program, 8 May 41. CWS 314.7 Educational Order Program File.

TABLE 4—CWS EDUCATIONAL ORDERS PROGRAM, FY 1939, 1940 & 1941 SUMMARY OF AWARDS

Items & Awardee	Quantity	Cost of Item	Cost of Gages, Jigs, M. & E.	Cost of Production Study	Total Amount of Contract
Service Gas Mask Assembly					
Goodyear Tire & Rubber Co.	3,000	....	....	....	$192,516
Firestone Tire & Rubber Co.	10,000	$62,986	$253,283	$12,000	328,269
Johnson & Johnson	10,000	64,500	270,159	5,000	339,669
Gas Mask Carrier					
Goodyear Tire & Rubber Co.	10,000	14,580	73,136	450	88,166
Non-Coconut Charcoal					
Barnebey-Cheney Eng. Co.	125T	96,312	222,600	2,000	320,912
Carlisle Lumber Co.	125T	76,090	206,900	1,000	283,990
CC-2					
E. I. du Pont de Nemours & Co.	1,000	173,250	201,300	3,850	378,400
Canister Components					
Milwaukee Stamping Co.	36,000	19,800	232,614	302	252,716
Faceblanks					
Firestone Tire & Rubber Co.	12,000	8,880	48,800	1,500	59,180
Goodyear Tire & Rubber Co.	12,000	9,840	48,470	750	59,060
Optical Faceblanks					
Acushnet Process Co.	3,000	8,820	34,200	500	43,520
Noncombatant Gas Mask					
Kember-Thomas Co.	10,000	41,043	104,725	450	146,218
Sprague Specialties Co.	20,000	78,640	96,521	2,500	177,661
Eureka Vacuum Cleaner Co.	10,000	42,446	90,853	1,750	135,049
Pitt. St. Fix. & Eq. Co.	10,000	39,950	94,705	500	135,155
B.K.B. Co.	10,000	47,900	102,654	1,200	151,754
Shoe Impregnite					
Baldwin Laboratories, Inc.	125T	72,286	43,033	1,000	116,319
Filter Paper					
Knowlton Brothers	25T	4,429	19,000	1,000	24,429
John A. Manning Paper Co.	25T	4,429	19,000	1,000	24,429
Whetlerite					
Barnebey-Cheney Eng. Co.	95T	6,669	53,766	500	60,935
Carlisle Lumber Co.	95T	6,602	54,525	500	61,627

Source: All the data in this chart, with the exception of the Goodyear Tire & Rubber Co. assembly contract, were taken from a study prepared by the Purchase Policies Branch, OC CWS, in 1945, entitled Analysis of Chemical Warfare Service Pricing Record World War II, p. 34. CWS 314.7 Educational Order Program File. This study makes no reference to the Goodyear assembly contract, which was the first contract under the Educational Order Program. The data on this contract were obtained in 1949 in a file of the Procurement Agency, Army Chemical Center.

TABLE 5—COST TO GOVERNMENT OF GAS MASK EDUCATIONAL PROGRAM

	Quantity	Total cost	Item cost	Mach. & equip.	Production study
Total		$2,643,888	$625,061	$1,987,925	$30,902
Service gas mask assembly	[a] 20,000	667,940	127,487	523,453	17,000
Gas mask carrier	10,000	88,166	14,580	73,136	450
Charcoal	250 tons	604,902	172,402	429,500	3,000
Whetlerite	190 tons	122,563	13,272	108,291	1,000
Canister components	36,000	252,717	19,800	232,615	302
Faceblanks	24,000	118,240	18,720	97,270	2,250
Optical faceblanks	3,000	43,520	8,820	34,200	500
Noncombatant masks	60,000	745,840	249,980	489,460	6,400

[a] This figure does not include the 3,000 masks procured under the Goodyear Tire & Rubber contract listed in Table 4, since full cost data were not available.

Source: Data in this chart were obtained from Analysis of Chemical Warfare Service Pricing Record in World War II, p. 35, prepared in 1945 by the Purchase Policies Branch, OC CWS.

period, the Munitions Program of 30 June 1940 and the subsequent appropriation acts which the Congress passed to finance that program enabled the service to advance to the toddling stage. The Munitions Program was a requirements and fiscal plan worked out by the War Department, the Advisory Commission to the Council of National Defense, and the President.[10] It became the new overall guide for all procurement planners.

In August 1939, when the war clouds were hanging heavy over Europe, the War Department undertook a quick review of its plans for emergency action. In this connection the Assistant Secretary of War called the chiefs of the technical services to his office on 19 August and outlined three more or less distinct phases through which the nation might pass in the change from peace to war. These phases were:

1. A period of neutrality when peacetime legislation was in effect and only current appropriations available.
2. A national emergency declared by the President and provisions of Section 120 of the National Defense Act invoked.
3. A declaration of war by the Congress.

The Assistant Secretary then listed a number of actions which his office or the Army and Navy Munitions Board would initiate in each of the

[10] (1) For details on the Munitions Program see Watson, *Chief of Staff: Prewar Plans and Preparations*, pp. 166–82, 318–21. (2) Smith, *The Army and Economic Mobilization*, pp. 126–33.

three periods and requested the chiefs of the supply services to send him a list of the steps they individually planned.[11]

Maj. Gen. Walter C. Baker, in his reply to this request on 21 August 1939, stated that during the present period of neutrality—Phase I—he was taking measures to: (1) accelerate all current procurement and educational orders then being planned; (2) round out Edgewood Arsenal; (3) request the removal of the field artillery garrison at Fort Hoyle, Md., and the incorporation of that reservation into Edgewood Arsenal; (4) present plans for the establishment of an additional manufacturing arsenal with necessary storage and range facilities; (5) freeze all completed specifications and drawings and expedite the completion of all others; (6) review and perfect plans for accomplishing and controlling procurement in war; (7) request funds to accumulate stockpiles of strategic materials; and (8) request the detail of selected Reserve officers for training in key positions connected with procurement.

Passing on to the second phase, that of the state of a national emergency, the Chief, CWS, said that he would: (1) request additional funds for carrying out requirements of the initial stages of a war; (2) start the construction of a new arsenal; (3) utilize to the greatest extent possible the productive capacity of industry; (4) prepare a war budget for the possible prosecution of a war through the second year; and (5) request a detail of additional selected Reserve officers for training in key positions connected with procurement.

Coming to the final phase, when the nation would be at war, General Baker listed only two steps: (1) the acceleration of all procurement programs in both government arsenals and commercial plants, and (2) the revision of existing procurement plans for a possible second year of war.[12]

During Phase I, the period of neutrality, the Assistant Secretary of War, Louis Johnson, personally took steps to insure that increased requirements for chemicals would be met in the event of war. Acting upon a suggestion of Edward M. Allen, president of the Manufacturing Chemists Association, he recommended early in 1939 that a national defense committee be set up to assist the War and Navy Departments in perfecting plans for utilizing the chemical industry should war break out.[13]

[11] Memo, Dir Plng Br OASW for C's Supply Arms and Services, 19 Aug 39, sub: Acceleration of Plans for Procurement. CWS 381/247-260 re War Plans.

[12] Ltr, C CWS to ASW, 21 Aug 39, sub: Procurement Planning CWS in Certain Contingencies. CWS 381/247-260.

[13] This information is contained in Ltr, Louis Johnson, Asst SW to E. M. Allen, 30 Mar 39. CWS 314.7 Chemical Advisory Committee to ANMB File.

MEMBERS OF THE CHEMICAL ADVISORY COMMITTEE *receiving Army Certificates of Appreciation from Brig. Gen. Alden H. Waitt, November 1945. From left (front): Charles S. Munson, Warren N. Watson, James W. McLaughlin, Harry L. Derby, General Waitt, Col. Harry A. Kuhn. From left (back): George W. Merck, Lammot du Pont.*

Mr. Allen, who was also the civilian chief of the New York Chemical Procurement District, had suggested that the district advisory committee be designated the Chemical Advisory Committee to the Army and Navy Munitions Board. This suggestion was adopted and from early 1939 until after the close of World War II the committee, whose members were leading representatives of the chemical industry, met monthly in Washington or New York.[14] Liaison officers from the Army and Navy Munitions Board, the Ordnance Department, and the CWS attended the meetings. A representative from the Advisory Commission to the Council of National Defense and, later, one from the War Production Board, were often in attendance.[15]

[14] Members of the committee were: H. L. Derby, chairman, E. M. Allen, H. F. Atherton, Charles Belknap, Willard H. Dow, Lammot du Pont, J. W. McLaughlin, George W. Merck, Charles S. Munson, and Warren H. Watson.

[15] Minutes of the meetings of the Chemical Advisory Committee are in files of the Manufacturing Chemists Association. Reproduction of these minutes and other data are in CWS 314.7 Chemical Advisory Committee File.

Upon its activation the committee called the attention of the War Department to the fact that its members might be suspected of conspiring to violate the federal antitrust acts. The War Department sought the opinion of the Attorney General of the United States on this matter. The Attorney General ruled that reports made by the Chemical Advisory Committee to the Army and Navy Munitions Board were considered confidential in nature and were therefore not subject to subpoena or investigation by other government agencies.[16] In other words, the recommendations of the committee were placed in the same category as war plans.

In 1939 and 1940 the committee set up fifteen commodity subcommittees which were responsible for making reports and recommendations to the parent committee. The reports covered such matters as consumption of specific chemicals by industries, means for transporting specific chemicals, and suggested locations for new plants. On the basis of production statistics and estimated industrial capacity furnished by the subcommittee as well as through statistics on military requirements furnished by the military services, the committee made recommendations on allocation of chemicals to the Army and Navy Munitions Board. Largely because of assistance which the Chemical Advisory Committee rendered during the emergency and war periods, chemical facilities were erected at the proper locations and the turnaround time on railroad cars carrying chemicals was cut down.[17]

Another development that facilitated preparations for chemical warfare under the Munitions Program was the receipt of pertinent information from the British. The assistant military attaché in London in the emergency period, a CWS officer, obtained access to data on development and production methods for chemical warfare items, on British smoke operations for screening critical installations, on the effects of incendiary bombing, and on the types of German incendiaries dropped on London.

[16] The ruling of the Attorney General is discussed in Ltr, Col Charles Hines, Secy ANMB to E. M. Allen, 17 Jul 40. In files of Chlorine Institute, New York City.

[17] (1) Interv, Hist Off with Charles S. Munson, who served on the Chemical Advisory Committee, 21 Jan 58. (2) Interv, Hist Off with Col Harry A. Kuhn, USA Ret, 20 Nov 57. Col. Kuhn was liaison officer to the Committee for CWS. (3) Ltr, E. R. Weidlein to Hist Off, 31 Jan 58. Mr. Weidlein was Chief of the Chemical Div of the Advisory Commission to the Council of Nat'l Defense and later Chief of the Chemical Div, WPB. (4) Ltr, E. W. Reid to Hist Off, 26 Feb 58. Mr. Reid succeeded Mr. Weidlein as Chief of Chemical Div, WPB. (5) Interv, Hist Off with Wilbur F. Sterling, 29 Apr 58. Mr. Sterling served as contact officer of ANMB to the Chemical Advisory Committee. (6) Minutes of the Meetings of the Chemical Advisory Committee. On 8 Dec 42, Robert P. Patterson, USW, and James Forrestal, USN, attended a meeting of the committee. Both expressed appreciation for the achievements of the committee to date and requested that the committee be continued during and after the war.

This information he sent to the Office of the Chief or to Edgewood Arsenal.

Appropriations

The Munitions Program would of course be merely an academic exercise without the money to implement it. As early as the fall of 1939 the Chief, CWS, again made an urgent appeal to the General Staff to take immediate steps to secure authorization and funds for rounding out the plant facilities at Edgewood Arsenal. Both the Assistant Chiefs of Staff, G-3 and G-4, concurred in the recommendation of the Chief, CWS, and suggested that a deficiency appropriation of approximately $5,500,000 be requested for this purpose.[18] This proposed request was conceived of just half a year ahead of the time when the Bureau of the Budget was in a mood to approve it. The temper of the bureau with regard to such requests was demonstrated by its action early in January 1940 when it excluded from the President's budget for fiscal year 1941 all supplemental estimates covering the "Critical Item Program," the "Essential Item Program," and the "Arsenal and Depot Facilities Program."[19] This was the winter of the "phony war" in Europe, and neither the Bureau of the Budget nor Congress was convinced of the need for greater expenditures for the Army. Hitler's invasion of Denmark and Norway in April and of the Low Countries and France in May changed their minds.[20]

Notwithstanding the action of the Bureau of the Budget in January 1940 the General Staff did not relax its efforts to gather all information possible on munition shortages preparatory to future requests for funds. On the very day after the Bureau of the Budget's action, for example, General Marshall requested G-4 to furnish him with a half page statement on Edgewood Arsenal, to include the approximate amount that had been invested in the installation along with additional "pieces" that the CWS might wish to add. The Chief of Staff wanted this information to enable him to withstand "pressure to reduce appropriations for Edgewood Arsenal in order to promote a large brand new arsenal somewhere else." In compliance with General Marshall's request he was furnished with the following information: Edgewood Arsenal was the only chemical warfare research, manufacturing, and chemical storage installation in the United

[18] Memo, ACofS G-3 for ACofS G-4, 10 Oct 39, sub: Status of Chemical Warfare Facilities. OCG, ASF-Edgewood Arsenal, Md.

[19] Watson, *Chief of Staff: Prewar Plans and Preparations*, p. 163, quoting Memo, SGS for AC'sofS, 10 Jan 40, sub: War Department Estimates, FY 1941.

[20] *Ibid.*, pp. 164-66.

States. The arsenal plants, with the exception of the gas mask assembly plant, were of the experimental type and not suitable for meeting the needs of the Initial Protective Force. The cost of constructing and maintaining the arsenal since 1917 was estimated at $43,600,000, with deterioration due to budgetary limitations at $29,100,000, making the value of the facilities as of January 1940, $14,500,000. The value of the existing stocks at the arsenal was put at $31,300,000. It was estimated that it would cost $5,000,000 to remove the stocks to a new arsenal. Therefore, it was planned to spend $5,400,000 to round out the plants at Edgewood Arsenal to enable it to meet the needs of the peacetime and the Initial Protective Force. The cost of a new arsenal of equivalent capacity was placed at $21,000,000 plus 8 to 10 million more for land. These data, according to the Acting Executive, Supply Division, G–4, were to be placed in the Chief of Staff's small information book where it would be considered confidential.[21]

The events in Europe in the spring of 1940 had their effect and by May the President and the Congress were in a very liberal mood indeed with regard to military appropriations.[22] On 16 May the President delivered in person a special message to the Congress on the need for supplemental outlays for national defense. On 13 June he signed the Military Appropriation Act of 1941 which provided for vast increases in military expenditures, and less than two weeks later, on 26 June, the first of five supplementals to the National Defense Appropriation Act of 1941.[23] The President had meanwhile received advice from General Marshall and William S. Knudsen, the newly appointed production authority on the Council of National Defense, on how this appropriated money was to be spent. Their decisions were embodied in the Munitions Program of 30 June 1940.

The appropriations to the CWS for fiscal year 1941 totaled $60,092,-532.[24] This figure was in contrast to the $2,091,237 appropriated for the previous fiscal year. The increased appropriations gave the CWS the green light to carry out its planned procurement and construction, and these programs got into actual operation in the summer of 1940.

[21] Memo, Actg Exec Supply Div G–4, 11 Jan 40, sub: Information for CofS. OCG, ASF–Edgewood Arsenal, Md.

[22] (1) Watson, *The Chief of Staff: Prewar Plans and Preparations,* p. 166. (2) For international background, see William L. Langer and S. Everett Gleason, *The Challenge to Isolation 1937–1940* (New York: Harper & Brothers, 1952), chs. XV and XVI.

[23] P.L. 611, 76th Cong, 3d Sess.

[24] Brophy and Fisher, *Organizing for War,* Table 1.

The amounts appropriated to the CWS were arrived at only after the most painstaking calculations. As previously, the CWS passed its estimates on to the General Staff, but in June 1940 Mr. Knudsen also become interested in the estimates. On 11 June Mr. Knudsen informed the Assistant Secretary of War that he wanted the answers to two questions: "How much munitions productive capacity does this country need and how rapidly must it become available?" [25] That Mr. Knudsen did not confine his attention solely to the broad aspects of these questions is shown by the fact that on the very day he made his inquiry he personally received a reply from the Chief, CWS, listing quantities and unit prices of critical items as approved by the War Department for procurement and manufacture by CWS, as well as supplemental lists of critical and essential items.[26] Six days later the Chief, CWS, in a memorandum to the Assistant Secretary of War, gave detailed data on the new arsenal and plant facilities that would be needed to meet the requirements of the PMP (1,000,000 men), and its augmentation to 4,000,000 men, and requested that the data be passed on to Commissioner Knudsen, who was evidently anxious to get the facts.[27] The Chief, CWS, listed the rehabilitation of Edgewood Arsenal which he estimated would require 15 months to complete, a new $21,000,000 arsenal to require 18 months, and $5,000,000 worth of government owned plants in industry to require 15 months to complete.

Facilities Expansion Gets Under Way

In July 1940 G-4 listed the immediate objectives of the CWS, under the Munitions Program in the following order of importance: first, rounding out Edgewood Arsenal; second, placing approved educational orders in industry (already considered above); and third, preparing plans for obtaining manufacturing plants in industry other than those covered by educational orders.[28]

The Appropriation Act for fiscal year 1941 carried an item of $918,988 for The Quartermaster General "for work authorized by the Act of June 4,

[25] Memo, Ex Asst to ASW for ASW, 13 Jun 40, sub: National Policy on Munitions Productive Capacity. CWS 381/247-260 (War Plans). Also quoted in Watson, *The Chief of Staff: Prewar Plans and Preparations*, p. 174.

[26] Memo, C CWS for W. S. Knudsen, 11 Jun 40, sub: Expenditure Program, CWS. CWS 381/247-260 (War Plans). A handwritten note on the margin of the carbon copy states that the memo was handed to Mr. Knudsen personally by Col A. M. Heritage, CWS, at 3:10 P.M.

[27] Memo, ExO OCWS for ASW, Attn Col Harry K. Rutherford, 17 Jun 40, sub: Munition Production Capacity, CWS. CWS 381/247-260 (War Plans).

[28] Memo, ACofS G-4 for CofS, 16 Jul 40, sub: Chemical Warfare Manufacturing Facilities at U.S. Nitrate Plant No. 1. G-4/30645.

1936 (49 Stat 1462) at Edgewood Arsenal, Maryland." [29] This was for construction of badly needed storage facilities. The First Supplemental to the Appropriation Act, signed on 26 June 1940, made the sum of $3,060,300 available to the Chief, CWS, for rounding out and rehabilitating Edgewood Arsenal.[30] These two appropriations of June 1940 enabled the CWS to initiate a program of construction which its chiefs had been advocating for years.[31]

In August 1940, General Baker, the Chief, CWS, directed Maj. Walter J. Ungethuem, chief of his War Plans Division, to supervise all construction activities at Edgewood. In September actual construction of new manufacturing plants was initiated under contracts drawn up by The Quartermaster General with the architect-engineering firm of Whitman, Requardt, and Smith of Baltimore and two construction companies, Riggs-Distler Co. of Philadelphia and Cummings Construction Co. of Baltimore. In November the General Staff ordered the erection of new troop barracks and gave approval to a CWS recommendation to enlarge the Chemical Warfare School. In the same month the long planned rehabilitation program of the deteriorating structures at Edgewood Arsenal was begun. All this building activity in the winter of 1940–41 resembled in scope that of 1917–18, when the arsenal was originally constructed. Although the forces of nature were considerably kinder in 1940–41 than they had been in 1917–18, winter days at Edgewood are often not too pleasant for outside work.[32] Since the Secretary of War insisted on the speedy consummation of construction projects, the commanding officer directed that work be carried on every day regardless of the weather.[33] It was not without significance that the funds in the Assistant Secretary's Office from which the CWS was allotted the money for arsenal construction were earmarked "Expediting Production Funds." The Chief, CWS, was constantly reminded of the importance of speed on this program.

By December 1941 the initial phase of the construction program at Edgewood was virtually completed. Old plants had been rehabilitated and

[29] WD Bull 11, 15 Jul 40, summarizes grants under the regular Appropriation Act for FY 1941 (P.L. 611, 76th Cong).

[30] (1) P.L. 667, 76th Cong. (2) Ltr, C CWS to USW, 9 Jan 41, sub: Defense of Procurement Activities Under Various 1941 Appropriations. CWS 400.12/6.

[31] See Rpts of CWS from 1931–38.

[32] This statement is based on detailed climatological data for the periods 1917–18 and 1940–41, furnished by G. N. Brancato, Meteorologist in Charge, U.S. Department of Commerce, Weather Bureau, Baltimore, Md.

[33] Ltr, Col W. J. Ungethuem, USA Ret, to Hist Off, 18 Jun 51.

a number of new facilities had been erected. These included manufacturing and filling plants, a new steam plant and distribution system, an entirely new sewage system with pumping stations and disposal plant, a research and development center, an airplane runway, a dock on Bush River, paved roads, new railroads, a new wing on the Chemical Warfare School, additions to the post headquarters building, several troop barracks, and two new training fields.[34] In addition, new depot facilities had been erected.[35] The actual cost of rehabilitation and construction came to over $34,000,000.[36] Within a period of sixteen months a considerable face lifting had taken place at Edgewood.

Government-Owned Contractor-Operated Plants

The preparation of plans for securing manufacturing plants in industry, which G–4 listed as one of the chief objectives of the CWS under the Munitions Program, was accomplished in 1940 and 1941. Under the Second Supplemental to the 1941 Appropriations Act, approved on 9 September 1940, funds were allotted to the CWS to erect plants for private industry in order to expedite production.[37] The procedure was for the government to build the plants which would be operated under contract with private industry. Both the Ordnance Department and the Chemical Warfare Service followed the practice extensively.[38] The CWS built charcoal and whetlerite plants and plants for the manufacture of impregnite (CC–2) under this program.[39]

Construction was begun on the first of these plants, a charcoal-whetlerite plant at Zanesville, Ohio, in December 1940 on the property of the Barnebey-Cheney Engineering Co.[40] The whetlerite portion of this plant

[34] (1) Annual Rpt, CW Center, EA, Md., FY 1942. Technical Library A CmlC, Md. (2) Appendix A.

[35] For details see below, p. 381.

[36] See app. A.

[37] P.L. 781, 76th Cong, 3d Sess.

[38] (1) ICAF R 83, Construction of New Facilities, January 1957, p. 47. ICAF Library. (2) Smith, *The Army and Economic Mobilization,* pp. 437–55.

[39] (1) Charcoal and whetlerite plants were in addition to similar plants built under educational order contracts. (2) Construction responsibility was divided between the Quartermaster and the Corps of Engineers until December 1941 when all construction activities were put under the latter. In the case of Ordnance and CWS plants, the using service was given the prerogative of selecting a prime contractor as management agent during the construction and during the operation of the completed facility. Jesse A. Remington and Lenore Fine, Construction in the United States, a Corps of Engineers volume in preparation for the series UNITED STATES ARMY IN WORLD WAR II, ch. II, p. 50.

[40] A charcoal-whetlerite plant had already been constructed on the Barnebey-Cheney property at Columbus, Ohio, under an educational order. This plant processed the charcoal of all the producers until other plants were put in operation.

was completed by 5 January 1942 and turned over for operation to the Pittsburgh Coke and Chemical Co. In April 1941 construction of a second charcoal-whetlerite plant was started at Fostoria, Ohio. This was completed by the beginning of 1942 and turned over to the National Carbon Co.[41] In February 1941, meanwhile, work had begun on the erection of impregnite plants at Niagara Falls, N.Y., East St. Louis, Ill., and Midland, Mich. These three plants were designed by Du Pont. The Du Pont Co. had been awarded an educational order contract in 1940 for an impregnite plant at Niagara Falls, N.Y.[42] At that time the Du Pont engineers had consulted CWS engineers and had surveyed the model impregnite plant at Edgewood Arsenal whose basic design had been drawn up by the Du Pont Co.[43] The plant which Du Pont constructed under the educational order contract thus represented the combined thinking of the CWS and Du Pont. On the basis of its experience in constructing the educational order plant the Du Pont Co. was awarded the contract to design the other impregnite plants. Du Pont itself was given the additional impregnite plant at Niagara Falls to operate, Monsanto Chemical Co. the East St. Louis plant, and Dow Chemical Corp. the Midland plant. The Site Location Board of the Office of the Assistant Secretary of War and the Advisory Commission to the Council of National Defense had to approve the sites for all these plants.[44]

Government-Owned and -Operated Plants and Arsenals

By the summer of 1941 the immediate objectives of the Munitions Program in the CWS were well on the way to realization and the service began to concentrate on some of the less urgent objectives. Among the latter were the construction of government plants for the impregnation of clothing, new government arsenals for the manufacture and filling of chemical warfare munitions, and additional storage space for the mass of new items being procured. In May 1941 the government awarded a contract to

[41] Interv, Hist Off with Sebastian W. Kessler, 11 Dec 57. Mr. Kessler was CWS engineer on construction of charcoal-whetlerite plants and he supervised their initial operation.

[42] See above, Table 4.

[43] (1) Interv, Hist Off with Col Robert D. McLeod, 12 Apr 54. Colonel McLeod, then a captain, was in charge of the CC-2 pilot plant at Edgewood in 1940. (2) Ltr, Brig Gen T. H. Marshall to Hist Off, 24 Jan 57. During World War II Marshall was on the Staff of the Technical Division, OC CWS.

[44] Memo, Col James H. Burns, OASW, for C CWS, 11 Jul 40, sub: Procedure on Munition Plant Construction Program, Awarding of Contracts and Supervision of Performance Thereunder. CWS 381/247-260.

the American Laundry Machinery Co. to design, construct, and install four plants to impregnate clothing at Columbus, Ohio; Ogden, Utah; Kansas City, Mo.; and New Cumberland, Pa. These government-owned and -operated plants, with the exception of the one at Ogden, were completed by 15 December 1941. The Ogden plant was dismantled before it was completed and shipped to England where it was erected at the Blythe Colour Works, Cresswell, near Stoke-on-Trent.[45]

The War Department, meanwhile, began to erect additional CW arsenals. In the years of peace, as mentioned above, the CWS had planned for one additional wartime arsenal in the central or western section of the United States.[46] On 30 April 1941 General Baker, in his final report to the Chief of Staff, again brought up the matter saying that he could not "stress too strongly the absolute necessity for the immediate authorization and construction of additional facilities other than those at Edgewood Arsenal at a location west of the Allegheny Mountains."[47] General Baker added that he knew consideration was being given to the construction of a new arsenal, but that to date no positive action had been taken.

Positive action was not taken until May 1941 when General Baker's successor, General Porter, became the sixth chief of the CWS. At that time several sites in the interior of the United States were being surveyed for a suitable location for a CWS arsenal.[48] On 18 June, Porter recommended selection of one of those sites, a stretch of flat lowland in the fertile valley of the Tennessee River near Huntsville, Ala.[49] The War Department approved General Porter's recommendation, and on 21 July construction of the new arsenal was begun. That same month the arsenal was designated an Army installation under command of Col. Rollo C. Ditto.

Lt. Col. Walter J. Ungethuem was transferred from Edgewood Arsenal where the building program was nearing completion, to supervise the construction at Huntsville. Accompanying Ungethuem were several engineers of the War Plans Division (later Industrial Engineering Division) of Edgewood Arsenal, who had worked on plans for a new CWS arsenal in the late thirties. These included two of the most experienced arsenal engineers in the CWS, E. C. Thompson and L. W. Greene. The CWS engineers

[45] (1) History of Pittsburgh CWPD, pp. 242-45. (2) Interv, Hist Off with Brig Gen Clifford L. Sayre, 22 Oct 56. Sayre was Chief of the Facilities & Engineering Branch, OC CWS, in World War II. (3) Ltr, Brig Gen T. H. Marshall to Hist Off, 24 Jan 57.

[46] See ch. X above.

[47] Ltr, C CWS to CofS, 30 Apr 41, sub: Final Report. CWS 319.1/2183-2449.

[48] History of Huntsville Arsenal from July 1941 to August 1945, p. 3.

[49] Ltr, C CWS to President WD Facilities Board OUSW, 18 Jun 41, sub: Additional Facilities, CWS. CWS 679/17.

GENERAL PORTER, *Chief of Chemical Warfare Service (holding pointer), discussing construction problems with General Ditto (left), Colonel Prentiss (right), and General Avery (second from right), in General Porter's office, Washington, January 1942.*

worked closely with the engineers of the firm of Whitman, Requardt, and Smith of Baltimore, which on 16 July was awarded a contract for architectural and engineering services for a new arsenal. On 21 July the Corps of Engineers awarded construction contracts to the following firms: C. G. Kershaw Contracting Co. of Birmingham, Engineers Limited of San Francisco, and Walter Butler Co. of St. Paul.

The Chief, CWS, in his recommendation for the construction of the new arsenal, listed the following facilities: four chemical loading plants, a chemical warfare depot, plant storage, laboratories, shops, offices, hospitals, fire and police protection installations, paved roads, and railroads. Construction under this program was getting well under way when the war began. The war period was to see the erection of many more facilities than originally planned.[50]

The decision of the Chief of Staff in the summer of 1941, to place entire responsibility for the incendiary bomb program with the CWS led to the need for still more facilities. The CWS surveyed industry and drew up a number of contracts for the production of these bombs.[51] Since this

[50] See app. A and B.
[51] See ch. XV below.

country had little experience in the manufacture of incendiaries and since there was a growing demand for them by both United States and the British forces, the War Department decided that the CWS should also manufacture and assemble incendiary bombs in government plants.[52] A pilot plant was erected at Edgewood, and in the fall of 1941 the Chief, CWS, obtained approval to construct an arsenal for this purpose at Pine Bluff, Ark., thirty miles southwest of Little Rock.[53] Col. Augustin M. Prentiss was named commanding officer of the new installation on 30 September 1941, and two weeks later the government awarded a contract for facilities for manufacturing and assembling incendiary munitions to Sanderson and Porter of New York.[54] The CWS arsenal engineers at Huntsville co-operated with the contractor in drawing the plans for Pine Bluff Arsenal, actual construction of which began on 1 December 1941. As at Huntsville, many more facilities than originally planned were to be constructed at Pine Bluff during World War II. Total cost of construction at Huntsville came to over $58,431,200 and at Pine Bluff to over $51,156,748.[55]

Procurement in the Emergency Period

Even while the new facilities were under construction at Edgewood Arsenal in 1940 and 1941 the manufacturing load rose sharply over that of previous years. Greater quantities of mustard gas, tear grenades, decontaminating apparatus, ton containers, 500-pound smoke clusters, smoke pots, and airplane smoke tanks were produced.[56] In the summer of 1940 the procurement districts began to engage in actual procurement, letting contracts for such items as 4.2-inch mortar shells,[57] components of the gas mask, and for assembling of the mask, charcoal, and smoke mixtures. Contracts were

[52] Ltr, Lt Col Charles E. Loucks, ExO OC CWS to Brig Gen H. K. Rutherford, OUSW, 26 Sep 41, sub: Outline of General Plan Incidental to the Procurement of Incendiary Bombs. CWS 679/17.

[53] This plant at Edgewood turned out the AN-M54 incendiary bombs which were used in Lt. Col. James H. Doolittle's raid on Japan, 18 Apr 42. See (1) Ltr, Brig Gen T. H. Marshall to Hist Off, 24 Jan 54. Marshall at that time was a captain working on the incendiary bomb program at Edgewood. (2) Seth Q. Kline, Robert E. Patchel, and Charles T. Mitchell, Development of Quick-Opening Cluster Adapters M4, M5, M6, M7, and M8 for Incendiary Bombs. TDMR 1015, 16 Apr 45.

[54] Pine Bluff Arsenal History, vol. I, p. 3.

[55] See app. B.

[56] CWS Rpt of Production 1 June 1940 through 30 July 1945.

[57] (1) Contracts for a limited number of shells were approved for training purposes and to build up the overseas reserve. Ltr, C CWS to USW, 9 Jan 41, sub: Defense of Procurement Activities Under the Various 1941 Appropriations. CWS 400.12/6. (2) Contracts for mortar shells were awarded in January 1941 to one prime and eight subcontractors in the Pittsburgh district. Hist of Pittsburgh CWPD, 1 July 1940 through 30 June 1945, pp. 192-93.

let to the lowest bidder and the OC CWS had to approve all contracts over $10,000.[58]

These increased activities led to organizational changes both in the chief's office and in the installations.[59] In July 1940 separate Procurement and Supply Divisions were established in the Office of the Chief and a year later, in a major reorganization by the newly appointed chief, General Porter, an Industrial Service was activated. Lt. Col. Paul X. English was named chief of the Industrial Service and Maj. Norman D. Gillet, chief of the Supply Division of the Industrial Service. After the initiation of contractual operations in the procurement districts in mid-1940 more Reserve officers were called to active duty and the district civilian personnel rolls were greatly expanded. District organizations resembling those planned in the peace years were put into operation. At Edgewood Arsenal an Arsenal Operations Department was activated in December 1940 to supervise manufacture, inspection, and service activities.[60]

Like all elements of the military establishment the CWS in the emergency period was faced with procurement problems caused by dislocations in the national economy. Perhaps the most significant of these problems was the low priority rating given chemical warfare items by the Army and Navy Munitions Board (ANMB), to which Donald Nelson of the Office of Production Management had delegated responsibility for War Department priorities.[61] In the summer of 1941 the board formulated a system of priority ratings ranging from A-1-a to A-1-j. Under this system chemical warfare items came under the low rating of A-1-i, undoubtedly because the board did not consider the need for such items as pressing as that of other items, which led at times to considerable delay in CWS facilities and production programs.[62] The construction of the charcoal-whetlerite plants at Zanesville and Fostoria in 1940 was delayed because the CWS was given a low priority for structural steel and steel plate, and in 1941 erection of the new impregnite plants was held up for the same reason. In 1941 also a considerable part of the gas mask factory at Edgewood had to be shut down temporarily because of low priorities.[63]

[58] Ltr, C CWS to CO's PD's and Arsenals, 13 Dec 41, sub: Authority to Contract. CWS 400.12/105.

[59] Brophy and Fisher, *Organizing for War*, ch. II.

[60] *Ibid.*, See chs. V and VI for a detailed discussion.

[61] ASF Annual Rpt for FY 1943, p. 66.

[62] For discussion of ANMB decisions on CWS priorities, see Conference, Manufacturing and Procurement Program of the CWS, 27 May 42, p. 6. CWS 314.7 Conferences File.

[63] (1) Advance Weekly Rpt CWS No. 12 to Statistics Br OUSW, 30 Jul 41. (2) Advance Weekly Rpt No. 14 to Statistics Br OUSW, 13 Aug 41. Both in CWS 319.1/70. (3) Kessler interv, 11 Dec 57.

MEETING OF CHEMICAL WARFARE SERVICE OFFICERS *to discuss procurement problems, Temporary Building F, Washington, D.C., October 1941. From left: Colonel Kuhn, Capt. Walter E. Spicer, Lt. Col. Henry Enterline, Col. Patrick F. Powers, Col. Hugh W. Rowan, General English, Capt. James H. Batte, Col. Sterling E. Whitesides, Jr., Col. Harry R. Lebkicher, Col. Raymond L. Abel, Lt. Col. John L. Miles.*

Another problem was the shortage of machine tools needed for the completion of contracts for components of the gas mask. Like most of the prewar procurement and supply problems in the CWS, this problem was national in scope. It originated in the large orders which foreign nations placed with the American tool builders before Congress had finally gotten around to appropriating considerable sums of money for national defense. As early as 30 July 1940 the Chief, CWS, expressed concern over the effect of the shortage of machine tools on the gas mask contracts.[64] The problem was not solved until well into the war period.

A third problem was the shortage of raw materials needed in the construction of new facilities and in the manufacture of munitions. With the War Department placing emphasis on rehabilitating Edgewood Arsenal and on building new plants and arsenals, meeting the raw material needs of the construction program was the most important immediate task. But shortages of needed materials for munitions also arose and these became more acute as time went on. By June 1941 material shortages were con-

[64] Ltr, C CWS to H. H. Pinney, President of E. W. Bliss Co., Brooklyn, N.Y., 30 Jul 40. CWS 011/21.

sidered so serious that the Under Secretary of War inaugurated a program in the technical services for the conservation of certain basic materials.[65] He drew up a list of the strategic and critical materials on the ANMB list and a few additional materials which had been placed under allocation or priority control by the Office of Production Management. Of particular interest to the CWS were aluminum, nickel, manganese, chlorine, rubber, copper, steel, cotton duck, and webbing. The Under Secretary directed the Chief, CWS, to conduct a continuous study of all specifications with a view to eliminating or reducing requirements for strategic materials which were under allocation or priority control. Even before receipt of the directive the Chief, CWS, had been investigating the possibility of replacing strategic materials in gas mask parts with plastic and steel.[66] To supervise all matters bearing on priorities, as well as to co-ordinate the growing problem of labor relations, a Priorities and Labor Relations Section was activated in the Industrial Service of OC CWS in August 1941.[67]

Still another problem of expanding procurement activities was plant protection. The Federal Bureau of Investigation inspected all War Department and contractors' facilities until the spring of 1941, when the function was transferred to the War Department itself. On 12 May the Under Secretary of War notified the Chief, CWS, of the change and outlined the activities to be carried out. He stressed the safety features of plant protection as well as the need for guarding against sabotage and directed that plant protection units be set up in the Office of the Chief and in the procurement districts. In conformity with this directive, the Chief, CWS, activated a plant protection unit in his office in May 1941 and instructed the chiefs of the districts to do likewise.[68]

One of the greatest difficulties of the period was meeting the need for trained inspectors. In the peacetime years all CWS inspection was carried on at Edgewood Arsenal under the supervision of the Inspection, Safety, and Proof Division. Inspection was on a 100 percent basis; that is, every major component was inspected on the manufacturing line and later each finished end item was inspected. In addition to the inspection of items being

[65] Memo, USW for C CWS, 11 Jun 41, sub: Conservation of Certain Basic and Semi-Finished Materials. CWS 381.388.

[66] Memo, ExO OC CWS for USW in reply to request of 11 Jun 41, sub: Conservation of Certain Basic and Semi-Finished Materials. CWS 381.388.

[67] OC CWS Organ Chart, 20 Aug 41. Capt. Alexander Leggin, a CWS Reserve officer, headed this section.

[68] Ltr, C CWS to ExO's all PD's, 13 May 41, sub: Plant Protection Inspection Service. CWS-1D 679.2C/11.

manufactured, there was a program of surveillance inspection under which chemical warfare matériel was periodically checked to determine the extent of its stability. This was done by making spot checks on matériel from a pilot or production plant or by conducting periodic tests on stocks in storage. Both the technicians and inspectors at Edgewood were vitally interested in these data.

The increase in CWS manufacturing activities led to the hiring in 1940 of a greater number of inspectors at Edgewood and in the districts. The older inspectors at Edgewood acted as a training unit for the new ones, the districts sending their apprentice inspectors to Edgewood for training before sending them out on the job. The concept of 100 percent inspection, as carried out at Edgewood Arsenal, was transferred to the districts and the new gas mask assembly plants such as that of the Goodyear Tire and Rubber Co. at Akron were planned and operated on that basis. During 1941 the number of inspectors at Edgewood and in the districts multiplied several times. To insure better methods of inspection, an analytical laboratory, a physical testing laboratory, and a gauge manufacturing and testing facility were set up at Edgewood Arsenal in 1941.

The increase in inspection activities in 1940 and 1941 led to several organizational developments in the chief's office. The most important of these were the activation of a Statistical, Inspection, and Specifications Section in 1940 and establishment of a separate Inspection Division in July 1941.

Mobilization of the Distribution System

Procurement of CWS items initiated under the educational order and munitions programs expanded still more as a result of the passage of the Lend-Lease Act in March 1941.[69] A few weeks after the act was passed, the War Department began revising its requirements upward. At the end of August President Roosevelt requested the War and Navy Departments to submit by 10 September their recommendations on how munitions produced in the United States should be distributed as between the United States, Great Britain, Russia, and other friendly powers during the period 30 August 1941 and 30 June 1942. The joint Army-Navy document compiled to fill the President's request became known as the Victory Program.[70]

[69] For details on effects of Lend-Lease Act on CWS activities, see ch. XVI below.

[70] (1) Smith, *The Army and Economic Mobilization,* pp. 133–39. (2) Watson, *The Chief of Staff: Prewar Plans and Preparations,* ch. XI. (3) M. M. Postan, "History of the Second World War," *British War Production* (London: Longmans, Green & Co, 1952), pp. 238–41.

COL. NORMAN D. GILLET

As CWS procurement grew in 1940 and 1941 the demand naturally arose for more storage space. Late in 1940 the CWS leased a large warehouse in Chicago and early in 1941 another warehouse in Indianapolis for the storage of gas masks acquired under the educational order program. Under the provisions of the Military Appropriation Act for the fiscal year 1941 over $12,000,000 was allotted to the Chemical Warfare Service for the construction of additional storage facilities. In July a construction program was initiated throughout the continental United States and in the overseas departments. Included within the depot program were the immediate construction of new facilities and the formulation of plans for the construction of additional storage space in the future. Two Reserve lieutenants were called to active duty to assist Major Gillet, chief of the Supply Division, OC CWS, in supervising the program. These officers collected data and drew up plans for modern storage depots where space would be utilized to the best possible advantage and where the latest handling equipment, such as fork lift trucks, would be used on an extensive scale.

After the enactment of the appropriation legislation the CWS began building new storage facilities at Edgewood in September 1940. Within a year the following new additions had been made: 6 warehouses, 13 magazines, 6 igloos, 2 sheds, 1 toxic gas yard, and 1 office. These facilities comprised over 360,000 square feet of storage space.[71] Between July 1940 and May 1941 the CWS acquired additional space in the War Department general depots at Ogden, San Antonio, Memphis, New Orleans, Atlanta, and in Panama, Hawaii, and the Philippines.[72] In the latter half of 1941 it was necessary to plan and arrange for modern storage depots at the new arsenals at Huntsville and Pine Bluff.[73] Actual construction of

[71] Scaggs, History of Eastern Chemical Warfare Depot, pp. 21 and 173.

[72] See app. A.

[73] (1) Ltr, C CWS to AG, 6 Oct 41, sub: Storage of 4-lb Incendiary Bomb and 1st Ind, AG, 112.05 (10-6-41) MC-D, 14 Nov 41. CWS 471.6/29 Conf. (2) Memo, C Fld Svc OC CWS to C Ind Svc OC CWS, 13 Nov 41, sub: Incendiary Storage at Pine Bluff and Huntsville. CWS 314.7 Incendiaries File.

TABLE 6—CWS DEPOT STORAGE SPACE IN OPERATION, DECEMBER 1941

[Thousands of Square Feet]

Space Category	Installation	Gross	Net Usable		
			Total	Occupied	Vacant
Warehouse	Total	769	545	345	200
	Chicago Warehouse	245	172	117	55
	Edgewood CW Depot	124	87	62	25
	Indianapolis Warehouse	181	126	110	16
	New Orleans POE	25	18	5	13
	New York POE	17	12	4	8
	San Antonio Gen. Depot	13	9	3	6
	San Francisco POE	32	22	9	13
	Shamokin, Pa	32	29	3	26
	Utah Gen. Depot	100	70	32	38
Igloo Magazine	Total	89	89	51	38
	Edgewood CW Depot	78	78	47	31
	Utah Gen. Depot	11	11	4	7
Shed	Total	19	14	7	7
	Chicago Warehouse	3	2	0	2
	Edgewood CW Depot	15	11	7	4
	San Antonio Gen. Depot	1	1	0	1
Open	Total	54	45	21	24
	Chicago Warehouse	16	12	0	12
	Edgewood CW Depot	38	33	21	12
Toxic yard (semifinished)	Edgewood CW Depot	93	37	28	9

Source: The figures in this table were compiled from data furnished by Supply Division, OC CWS, in 1946.

those facilities was not undertaken, however, until early 1942.[74] (*Table 6*)

While the Supply Division, OC CWS, was planning new depots and acquiring additional storage space, the immediate need arose of furnishing gas masks to troops being inducted into the rapidly expanding Army. In order to prevent delay in delivery, the Supply Division made arrangements to transport the masks and some other equipment directly from the point

[74] (1) See app. A. (2) Table 6 shows the amount of CWS storage space as of December 1941.

of manufacture to post, camps, and stations. This direct delivery, which characterized the period from the fall of 1940 to early 1942, enabled the CWS to carry on its program of depot planning and construction without having to expand its current storage activities. During 1941 gas masks and gasproofing equipment in considerable quantities were also shipped to Puerto Rico, the Canal Zone, the Philippines, and Hawaii.[75] This equipment was put to good use in the Malinta Tunnel on Corregidor before the final surrender of the American troops.[76]

Procurement and supply developments in the two years preceding U.S. entrance into war placed the CWS in a better position to meet the demands of a full-scale conflict. Thanks to the educational order program and the Munitions Program of 30 June 1940, the CWS was able to build new facilities and undertake procurement in the districts and arsenals. Had such construction not been undertaken, the state of CWS preparedness at the time of the outbreak of war would have indeed been tragic. Moreover, by obtaining experience in the production and inspection of munitions, drawing up contracts, and storing and issuing equipment, CWS personnel—military and civilian—were in a much better position to cope with the problems which would confront them after the war got under way. The problems that arose, such as shortages of raw materials and low priorities, were to continue and become even more acute once the nation entered the war.

[75] (1) Ltr, ExO OC CWS to CO Columbus Gen Dep, 19 Feb 41, sub: Shipment of Gas Masks. (2) Cablegram, Baker to CmlO Philippine Dept, 8 Apr 41. (3) Memo, CmlO Hawaiian Dept for C CWS, 11 Sep 41. (4) Cablegram, Porter to CmlO Philippine Dept, 12 Sep 41. All in CWS 470.72/181.

[76] Pritchard, Kleber, and Birdsell, Chemicals in Combat.

CHAPTER XII

More and More of Everything

CWS procurement and supply activities increased tremendously in World War II, reaching proportions never contemplated in the prewar years. Figures on dollar value (*Table 7*) and the production of selected items (*Table 8*) give some indication of the volume of CWS procurement. Although the CWS program was small when compared to those of other technical services (*Chart 1*), the fact that it amounted to over a billion and a half dollars definitely placed it in the class of big business. The CWS procured matériel not only for the Army but also for the Navy, as well as for coun-

TABLE 7—SUMMARY OF ESTIMATED DOLLAR VALUE OF CWS PROCUREMENT: 1940–1945 [a]

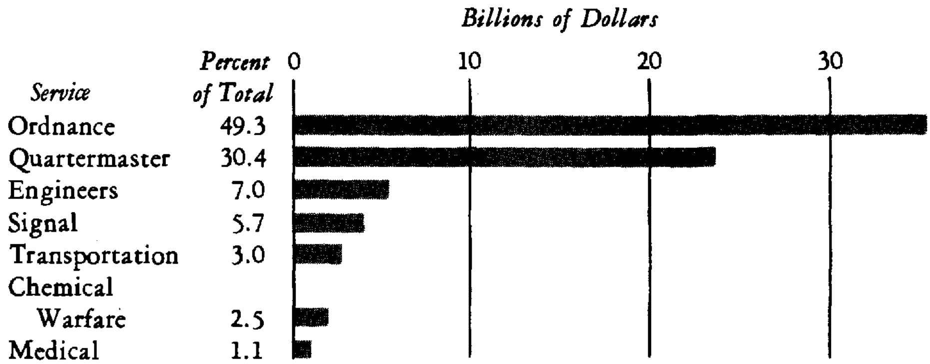
[Thousands of Dollars]

Major Groups	Total	Jul 40–Dec 41	1942	1943	1944	1945
All CWS Materiel.	$1,746,008	$46,656	$207,209	$470,961	$638,324	$382,858
Munitions, other than Bombs	353,507	5,431	42,760	83,768	135,686	85,862
Bombs	727,206	302	50,331	161,465	305,772	209,336
Protective Materiel	404,444	35,636	84,446	159,122	85,720	39,520
Weapons	39,390	13	4,438	6,665	15,273	13,001
Service Equipment	49,723	2,143	10,255	19,389	14,750	3,186
Miscellaneous	171,738	3,131	14,979	40,552	81,123	31,953

[a] Value computed by Hqs, Army Service Forces, from physical quantities of materiel delivered in each year multiplied by unit costs in 1945. The data, therefore, reflect physical volume rather than actual cost to or total expenditure of funds by the government.

Source: Crawford, Cook, and Whiting, Statistics, "Procurement." MS in OCMH.

CHART 1—TOTAL ARMY SERVICE FORCES ESTIMATED DOLLAR VALUE OF PROCUREMENT DELIVERIES BY TECHNICAL SERVICES: 1 JANUARY 1942—31 DECEMBER 1945



Source: Crawford, Cook, and Whiting, Statistics, "Procurement," *passim.*

tries included in the Lend-Lease Act. The total value of CWS items procured for the Navy amounted to about $150,000,000 and for lend-lease countries to almost $303,000,000.[1]

Procurement of Service Equipment

In addition to toxic, incendiary, and smoke ammunition and bombs, as well as chemical warfare offensive weapons and equipment, the CWS was responsible for the procurement of a variety of service equipment. The latter included a truck mounted with a swinging boom crane, a chemical service truck, a chemical service trailer, a unit for mixing toxic and incendiary agents in the field, and a set for maintaining and repairing chemical warfare equipment in the field. Several of these items presented unusual problems of development and procurement.[2] (*Table 8*)

The truck, crane, swinging boom, was designed to handle ton containers of toxics and was prescribed equipment for airfields where chemical

[1] The figure on Navy procurement was supplied by the Supply and Distribution Div, OC CWS, in 1946. The figure on lend-lease was obtained from WD Lend-Lease Transfer, CWS, May 46.

[2] Unless otherwise indicated, discussion of items of service equipment is based on History of Chicago CWPD, 1 Jan 45–15 Aug 45; CWS Report of Production 1 Jan 40 through 31 Dec 45, pp. 27, 31; and Interv, Hist Off with Lt Col Robert C. Hinckley, 9 Jan 58. Col. Hinckley was Chief, Procurement Division, Chicago CWPD in World War II. The CWS procured most of its service equipment through that district.

TABLE 8—EXPANSION IN PRODUCTION OF SELECTED CW ITEMS, WORLD WAR II

Item	On Hand as of 12 Dec 41 [a]	Procured 1 Jan 42 to 31 Dec 45 [b]
Mask, gas	5, 417, 078	31, 739, 356
Set, Antidim	1, 739, 850	7, 244, 947
Ointment, Protective (tubes)	152, 431	57, 542, 597
Curtain, gasproof	38, 816	741, 998
Kit, repair	439, 674	819, 334
Laboratory, Field	3	24
Apparatus, demustardizing (3 gal.)	53, 659	230, 297
Apparatus, decontaminating, P–D	6	4, 561
Agent, demustardizing, bleach (tons)	501	33, 307
Impregnite (Protective clothing) (tons)	456	18, 816
Impregnite (Shoe) M1 (tons)	1, 660	15, 242
WP Smoke (tons)	436	78, 207
H (tons)	4, 137	82, 451
FS (tons)	361	23, 370
CG (tons)	893	19, 001
CNS (tons)	9	1, 588
1 Ton Containers	5, 154	89, 980
Tank, Airplane, Smoke	812	124, 181
Incendiary Bombs, 2, 4, 6, and 10 lbs	0	254, 793, 060
Mortar Chemical, 4.2″	44	8, 498
Flame Thrower	12	41, 452

Source: [a] Weekly Report for Chief of Staff, CWS Munitions on Hand as of December 12, 1941.
[b] Crawford, Cook, and Whiting, Statistics, "Procurement," pp. 21–24, and CWS Report of Production 1 Jan 40 through 31 Dec 45. Because of the inclusion in this column of certain minor items not considered in Crawford, Cook, and Whiting, some of the totals shown above differ slightly from those in that study.

air service companies were stationed. The service companies were responsible for delivering toxic, smoke, and incendiary bombs to the apron for aircraft loading by Army Air Forces crews. As soon as other services observed how the unit performed, they began using it on jobs for which it had not been intended. For example, it was frequently used to remove wrecked aircraft from fields. Projects such as this were simply too heavy for the mechanism and the truck frequently broke down. The CWS procured the truck, crane, swinging boom, from Gar Wood Associates, Inc., Washington, D.C., which developed the telescopic boom and power take-off. These were mounted on a 4-ton tractor chassis furnished under subcontract by the Diamond T Co. About 400 of the units were assembled at the Diamond T rebuild plant near Detroit.

The chemical service truck was used to facilitate the loading and handling of chemical containers, such as smoke tanks, ton containers, and 55-gallon drums. The Ordnance Department supplied the 6 by 6 chassis for the truck while the CWS contracted with several firms for mounting the superstructure, which consisted of a monorail frame with a chain hoist, chocks, and equipment lockers. Though development and manufacture of this item proceeded with no more than an average number of obstacles, the task of obtaining priorities for the necessary materials did present a knotty problem. The CWS procured more than 3,000 of these trucks during the war.

Procurement officials experienced some difficulty in getting chemical handling and chemical service trailers because of the failure of the chief prime contractor, the Saginaw Products Corp. of Saginaw, Mich., to obtain critical components on time. These trailers resembled the M5 bomb trailers which the Saginaw company manufactured for the Ordnance Department in that both types featured a special design on which Saginaw Products Corp. held a patent. The special design consisted of two front bogie wheels with electrical brakes and a device that enabled the trailer to cut loose from its tow truck and come to a stop at a specified point. This feature did not always work well. The service trailer, like the service truck, was equipped with beam and hoist, while the handling trailer was designed to carry toxic containers and smoke tanks. The CWS procured over 2,300 of the handling trailers and over 250 of the service trailers.

The service assembled 114 maintenance repair sets for chemical equipment at Edgewood Arsenal between August 1942 and July 1945. These sets consisted essentially of special tools needed for hand-tool repair of flame throwers, collective protectors, air compressors, and portable decontaminating apparatus, as well as gas mask repair tools and test equipment. No single item of field equipment supplied by the CWS proved more useful to the chemical officer in the field than did this set.

Procurement of Chemicals

The CWS was also responsible for procurement in appreciable quantities of 374 chemicals in World War II.[3] A few of these, such as toxic agents, decontaminating agents, and napalm, were end items. The others

[3] See Consolidated Chemical Commodity Report, 16 Oct 51. The number 374 does not include chemicals used for experimental purposes at CWS laboratories, where many more chemicals, sometimes in insignificant amounts, were used. CWS 314.7 Procurement File.

were components and process chemicals used in the manufacture of chemical warfare items. Although the CWS manufactured certain basic chemicals such as arsenic trichloride, sodium hypochlorite, and chlorine at its own arsenals, it purchased the vast bulk of the basic chemicals from some 600 firms throughout the United States. Since the home offices of most of these companies were in New York City, the OC CWS in November 1941 decided to centralize preliminary negotiations for procurement of chemicals for the incendiary bomb program in that district.[4] A year later the entire Chemical Section, Industrial Division, of the chief's office, was transferred from Washington to New York.[5] In the summer of 1944, the Chief, CWS, directed that this section be raised to the status of a division to be known as the Chemical Commodity Division, OC CWS. From that time until the close of the war this division, whose chief was Col. Samuel N. Cummings, supervised the procurement of chemicals at all CWS arsenals and procurement districts.[6]

While procurement of most chemicals was usually a simple commercial transaction, in the case of some half-dozen real complications arose. This half-dozen included hexachloroethane for smoke mixture, thermite, barium nitrate, barium chromate, magnesium for incendiary bombs, and chlorine.[7]

Among the basic chemicals, none was considered more important than chlorine, if the extent of CWS planning and the quantity of the item procured are taken as criteria. Although chlorine was used on the battlefield in World War I, the CWS in the postwar years decided against using it as a toxic agent. It was nevertheless an essential component not only of other toxic agents, but also of smoke, protective ointment, bleach, and other decontaminating substances. In the mid-1930's the CWS began to give serious consideration to planning for emergency production of chlorine. The planners in the Office of the Chief made a study of wartime requirements and concluded that it would be necessary to construct an electrolytic caustic plant at Edgewood Arsenal capable of producing 150 net tons of chlorine a day. The CWS believed that its additional war demands

[4] Memo, C Ind Svc, OC CWS, for CO Pittsburgh CWPD, *et al.*, 5 Nov 41, sub: Procurement of Chemicals for Incendiary Bomb Program. CWS 400.171/551.

[5] OC CWS Adm O 6, 6 Nov 42.

[6] (1) Memo, C Ind Div, OC CWS, for all Procurement Districts, 27 Jul 44, sub: Establishment of a Chemical Commodity Division. CWS 400.12 OC CWS Procurement, Chicago CWPD. (2) Interv, Hist Off with Col Samuel N. Cummings, 26 Aug 54. (3) History of Chemical Commodity Procurement, 1 Aug 44–13 Nov 45.

[7] For discussion of procurement of chemicals used in smoke and incendiaries see ch. XV below.

of 550 net tons a day could be met by the chlorine industry through expansion of existing capacity by 40 percent. In the event of an emergency, according to CWS plans, the government would provide funds for expansion of chlorine plants, but the industry was expected to draw up plans for expansion at its own expense. In the fall of 1935 the Chief, CWS, disclosed this idea, in confidence, to the leaders of the chlorine industry. This he did by communicating with the president of the Chlorine Institute in New York City. The Chlorine Institute found its members receptive to the suggestion.[8]

Among the subcommittees of the Advisory Committee to the Army and Navy Munitions Board was one on alkali-chlorine.[9] Set up in the fall of 1939, this subcommittee, whose members were leaders of the industry, continued throughout the war to assist the government in meeting demands for alkali and chlorine products. The subcommittee met periodically in New York City. In attendance was a CWS officer, Col. Harry A. Kuhn. Kuhn was responsible for gathering statistics on production from the manufacturers and passing these on, together with estimates of government requirements, to the Chemical Advisory Committee. From 16 December 1941 to the end of the war a U.S. Naval officer also attended meetings of the Alkali-Chlorine Subcommittee.[10]

The emergency period witnessed a steadily increasing demand for chlorine. With the inauguration of its procurement program in the summer of 1940, the CWS circulated bids for the delivery of some 3,780 net tons to Edgewood Arsenal to be used in the manufacture of toxic agents. In 1941 the demand continued to rise, especially after passage of the Lend-Lease Act. On 19 March the Office of Production Management put chlorine on the priority critical list, and there it remained throughout the war. By July about 30 percent of the country's chlorine was being channeled into war uses.[11]

In the prewar period the CWS had to depend entirely on industry for chlorine. This arrangement was not satisfactory for there were delays in

[8] (1) Ltr, C CWS to S. W. Jacobs, [President, Chlorine Institute], 10 Sep 35. This letter gives a brief summary of CWS plans. (2) Ltr, S. W. Jacobs to C CWS, 6 Feb 36. Both in files of Chlorine Institute, New York City.

[9] See ch. XI above.

[10] Minutes of Meetings of the Alkali-Chlorine Committee are in the files of the Chlorine Institute, New York City. Copies of the most pertinent minutes are in CWS 314.7, Chlorine Institute File.

[11] (1) "Report on Chlorine Industry," *Chemical and Metallurgical Engineering*, vol. 51 (1944), pp. 115–22. (2) Robert T. Baldwin, "Chlorine in World War II," *Armed Forces Chemical Journal*, III (October 1948), 29–32. (3) Minutes of Meeting of Alkali-Chlorine Subcommittee, 2 Jul 40. In files of Chlorine Institute, New York City.

transporting the chemical. In January 1942, therefore, the War Production Board advised the Chemical Warfare Service to obtain chlorine from its own facilities.[12] The CWS, as indicated, had made plans in the peacetime period for construction of a chlorine plant at Edgewood Arsenal capable of producing 150 tons a day. When construction of Huntsville Arsenal was undertaken in the summer of 1941, these plans were modified to provide for a 100 ton a day plant at Huntsville and a 50 ton a day plant at Edgewood. Later a 50 ton plant was built at Pine Bluff and a 100 ton plant at Rocky Mountain Arsenal. These plants were thus capable of turning out 300 tons of chlorine a day, but because gas warfare did not materialize they were not all run to full capacity. Total production at the CWS arsenals ran to something less than 370,000,000 pounds.[13] In addition to this chlorine, which was used principally in the manufacture of toxic agents, the CWS bought over 64,000,000 pounds through the procurement districts, for use chiefly in the manufacture of decontaminating agents and for CC-2 manufactured at the Niagara Falls plant.[14] Some other CC-2 plants produced their own chlorine.[15] Wartime consumption of chlorine, military and civilian, exceeded the estimates of both the peacetime planners and of the chlorine industry. From a total of 696,472 tons in 1940, production in private industry jumped to a yearly wartime peak of 1,343,956 tons in 1944.[16]

By the fall of 1943 the CWS had accumulated a surplus of chlorine while the civilian demands for the chemical and for its by-product, caustic soda, were not being filled. Under an arrangement agreed upon by the War Production Board, the Army Service Forces, and the Chemical Warfare Service, CWS arsenals sold excess chlorine and caustic soda to private industry.[17]

Estimating Requirements in Wartime

A significant feature of the CWS procurement program in World War II was the inclusion of several important end items not planned for in the pre-

[12] Notes for Gen Porter ANMB Advisory Committee [Meeting], Cosmos Club [Washington], 7 Dec 42. CWS 314.7 Advisory Committee File.

[13] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 21.

[14] Consolidated Chemical Commodity Report, 16 Oct 51, p. 74.

[15] Interv, Hist Off with Col Harry A. Kuhn, 27 Jan 58.

[16] Baldwin, "Chlorine in World War II."

[17] (1) Memo, Prod Div ASF for C CWS, 20 Aug 43, sub: Solid Caustic Soda. (2) Ltr, Lt Col L. W. Munchmeyer, Ind Div, OC CWS to CG Prod Div, ASF, sub: Solid Caustic Soda. (3) Ltr, Dir of Prod Div, ASF for Dir Chemical Div, WPB, 21 Sep 43, sub: Solid Caustic Soda. All in files of Planning Div, ASF. (4) Interv, Hist Off with J. C. Leppart, 5 Mar 58. Leppart was with the Chemical Div, WPB, in World War II and was instrumental in bringing about the arrangement on sale of CWS excess supply of chlorine and caustic soda.

war years. As late as the fall of 1941, CWS requirements under the Victory Program made no mention of 4.2-inch mortars, 4.2-inch mortar shells, or flame throwers. It listed other gas warfare items, both offensive and defensive, and certain types of incendiaries, and estimated, sometimes with astounding accuracy, the quantities of such material that would be needed during the war.[18] The Victory Program, in a word, did an excellent job of estimating CWS requirements in terms of the CWS mission as it was then envisioned, but it did not (and could not) take into account ramifications of the CWS mission as it developed in 1942.[19]

The Office of the Chief, CWS, estimated requirements for chemical warfare items, other than ammunition and toxics, on the basis of the planned size and composition of the Army. The size of the Army was projected by totals of types of organizations and units and by totals of individuals. Each arm and service evolved tables of organization and equipment for the units under its jurisdiction. Each technical service, including the CWS, then worked out tables of basic allowances for each type of organization and unit, specifying the material the service would furnish the organization or unit as a whole and the individuals within the unit. The total material to be provided under tables of basic allowances therefore comprised the initial issue requirement for items provided by the service. Early in the war factors for resupply, maintenance, and distribution were assigned rather haphazardly. The total of the items required under these factors plus the initial issue requirement equaled the first procurement objective of the service. Ammunition requirements were computed on the basis of the unit of fire per weapon. Units of fire were determined by the War Department General Staff, in co-operation with the Army Ground Forces and the Army Service Forces, on the basis of the firing potential of each weapon as adjusted by contemplated usage of weapon in operation. The unit of fire method of determining requirements was only as good as the estimate of operational usage, which proved a poor basis for computation prior to the availability of experience data. Toxic requirements during World War II were determined by the United States Chemical Warfare Committee.[20]

All chemical warfare requirements were subject to review by the War Department General Staff (G-4), and later by Headquarters, ASF, before

[18] Joint Board Estimate of United States Overall Production Requirements 11 Sep 41. [Victory Program] Jt Bd No. 355 Ser. 707.

[19] See Brophy and Fisher, *Organizing for War,* ch. III.

[20] See Brophy and Fisher, *Organizing for War,* ch. IV, for discussion of USCWC.

being passed on to the Munitions Assignments Board and other agencies of the Joint and Combined Chiefs of Staff. In the summer of 1941 when the computation of requirements was beginning to assume the proportions of a major activity, the Chief, CWS, established a separate Planning Division in his office to perform this function.

In November 1941 Brig. Gen. Brehon B. Somervell was appointed Assistant Chief of Staff, G-4, War Department General Staff. This appointment was to have a marked effect on the development of requirements procedures as well as on all procurement and supply activities in the Army. The new G-4 soon came to learn that civilian agencies responsible for determining the production capabilities of the nation for war, such as the Office of Production Management (OPM), were critical of the Army's estimates of requirements. Somervell came to the conclusion that what the Army needed was a single comprehensive report reflecting military needs and the ability to fill such needs. Such a report was devised in early 1942 in the form of the Army Supply Program, which listed estimated requirements for two and sometimes three years ahead. This directive, issued periodically and in several parts, was the overall Army directive for procurement and supply during the first two years and more of the war.

When General Somervell was appointed commanding general of the Army Service Forces in March 1942 he took most of his G-4 organization with him. From that time until the end of the war the CWS, as a technical service of the Army, usually reported directly to ASF headquarters on procurement and supply activities.[21]

The day war was declared on Japan the Planning Division, OC CWS, was combined with the Fiscal Division.[22] Computing requirements was apparently considered so closely related to fiscal matters that both activities were put under the jurisdiction of a single agency, the new Fiscal and Planning Division. Whatever the seeming justification, there were serious drawbacks to the arrangement. This the War Department came to realize, and in August 1942 it directed that fiscal officers confine their activities strictly to fiscal and budgetary matters.[23]

Actually the estimating of supply requirements was more closely related to the drawing up of operational plans than to fiscal matters. The

[21] (1) John D. Millett, *The Organization and Role of the Army Service Forces,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1954), pp. 1-8. (2) Smith, *The Army and Economic Mobilization,* ch. VII. (3) SOS, Administrative Order (Adm O) 38, 16 Sep 42.

[22] OC CWS Off O 40, 8 Dec 41.

[23] WD Cir 280, 21 Aug 42.

decision of the chief's office to set up a Field Requirements Branch in the Operations Division in the fall of 1942 was therefore sound. As part of the reorganization of General Porter's Office in May 1943 the Field Requirements Branch was raised to the status of a division under the jurisdiction of the Assistant Chief, CWS, for Field Operations, General Waitt.[24] It had final responsibility for chemical warfare requirements until the end of the war. While the Field Requirements Division had ultimate responsibility for chemical warfare requirements for the ground forces, two other elements of the chief's office, the Supply Division and the Control Division, worked on the computation of those requirements. The Supply Division needed requirements data in order to carry out its mission of storing and issuing matériel, while the Control Division had the responsibility of correlating all statistical data transmitted from the OC CWS to higher echelons. With the inauguration of the supply control system throughout the ASF in March 1944, the CWS set up a Materiel Planning Branch and a Requirements Planning Committee to work on requirements.[25]

Three factors had to be considered in calculating supply requirements during the first two years of the war—initial equipment, maintenance, and building up a reserve of material. Special difficulty arose in calculating maintenance and reserve factors because there was no field experience on which to base estimates, which were at times nothing more than educated guesses. The problem was not confined to the CWS but was general throughout the Army, and occupied the attention of ASF headquarters throughout most of 1943.

The CWS confined itself to estimating requirements for the ground forces, leaving the task of estimating Air Forces chemical warfare requirements to the Air Corps and later to Headquarters, AAF. The AAF requirements for chemical warfare items, particularly incendiary bombs, were high. Among the duties of the Air Chemical Officer was that of assisting the AAF in estimating their chemical warfare requirements. Shortly after the outbreak of war, Lt. Col. Thomas A. Doxey, Jr., CWS, was appointed to this post. Late in 1943 Colonel Doxey was succeeded by Col. Edward Montgomery.

The factors that were considered in estimating the chemical warfare requirements of the AAF were the number of planes to be operated, the sortie rate, the bomb load per sortie, and the types of bombs to be used.

[24] Brophy and Fisher, *Organizing for War*, ch. V.
[25] See ch. XIII below for details.

As experience data became available, statistics on actual expenditure, on theater levels of supply, and on transit time were utilized.[26]

In arriving at chemical warfare requirements the Office of the Air Chemical Officer worked closely with the Requirements Division of the Assistant Chief of Air Staff for Operations Commitments and Requirements, which correlated all AAF requirements. Once the requirements were computed they were included in the Army Supply Program. Administratively the Office of the Air Chemical Officer was under the jurisdiction of the Assistant Chief of Air Staff for Matériel, Maintenance and Distribution, after that office was established in March 1943.[27] It devolved upon the Air Chemical Officer not only to estimate chemical warfare requirements, but to check closely with the CWS to see that the requirements were translated into actuality, for the CWS procured all AAF chemical warfare items. In accomplishing its mission the Office of the Air Chemical Officer, as a representative of and speaking for the Commanding General, AAF, dealt directly with OC CWS. On matters of policy or command the Air Chemical Officer conducted correspondence through the Commanding General, ASF.

Facilities Expansion in Wartime

The chief impediments to full production in 1942 and the early part of 1943 were shortages of facilities, shortages of manpower, difficulty in obtaining suitable contractors to handle the ever expanding volume of procurement, technical problems inherent in the initial manufacture of noncommercial items, shortages of raw material, and imbalances in the supply of materials and components. There was also a need for certain refinements in organization and administrative procedures in the CWS and among higher echelons of the government. In some instances, as indicated above, the problems had already risen in the prewar period, and merely became more complicated after entrance of the United States into the war.

Of more immediate concern than estimating requirements was providing facilities for the manufacture of matériel. The construction program

[26](1) Note in Diary of Air CmlO, 27 September 1943, quoting a memo for Munitions Assignment Board on sub: Review of Combined Resources and Requirements on Incendiary Bombs. CWS 314.7 Air CmlO File. (2) Interv, Hist Off with J. S. Entriken, 19 Jun 56. Entriken was on active duty as requirements officer in office of Air Chemical Officer from December 1943 until the end of World War II. (3) Wesley Frank Craven and James Lea Cate, eds., "The Army Air Forces in World War II," vol. VI, *Men and Planes* (Chicago: University of Chicago Press, 1955), p. 378.

[27] Craven and Cate, *Men and Planes*, p. 44.

which got under way in the emergency period was greatly accelerated after the outbreak of war. At the time of the Pearl Harbor attack, none of the manufacturing plants at the new arsenals was completed and Edgewood was still the sole source of all types of chemical agents.

The years 1942–43 saw the number of CWS facilities increased several times over. In addition to the erection of most of the plants at Huntsville and Pine Bluff, a third new CWS arsenal, Rocky Mountain, was built outside Denver. Here the government acquired some 20,000 acres of land, the southern boundary of which was adjacent to the city limits of Denver. The choice of this site was a happy one. Considered relatively immune from attack by air, it was near the main lines of the Chicago, Burlington, and Quincy and the Union Pacific Railroads, and to main highways. The climate was favorable and there was an adequate supply of electric power furnished by the Public Service Company of Colorado. Irrigation water from the Platte River was available for industrial purposes, but potable water had to be brought in by laying about ten miles of piping to connect with the Denver water system.[28]

In the construction of this last CWS arsenal, of which Lt. Col. Marshall Stubbs was named first commanding officer on 2 June 1942, the CWS benefited from its experience in planning and building the earlier arsenals. In mid-June Colonel Ungethuem, who had supervised the new construction at Edgewood and later at Huntsville, was transferred to Rocky Mountain to lend assistance. The War Department awarded prime contracts to Kershaw, Swinerton, and Walberg of San Francisco and Birmingham, and H. K. Furgeson Co. of Cleveland to build the arsenal. Contracts as design consultants were awarded to H. K. Furgeson and Du Pont, and architect-engineer contracts to Whitman, Requardt, and Smith of Baltimore, and Kershaw, Heyer, Swinerton, and Walberg of San Francisco and Denver.[29]

In 1942 construction was also begun on two government-owned and privately operated plants and in 1943 on another five such plants. Besides the construction work done on arsenals and plants, the following major CWS facilities were erected in whole or part in 1942–43: Camp Sibert, Deseret Depot, Dugway Proving Ground, and Camp Detrick. In 1944, when War Department construction had been virtually completed, addi-

[28] History of the Rocky Mountain Arsenal, 1945, vol. I, pt. 1, pp. 3, 171–79.
[29] (1) *Ibid.*, p. 9. (2) RMA Post Diary (2 May 42–30 Sep 43).

tions were made to the arsenals and two more manufacturing plants were built.[30]

From 1 July 1940 to 31 December 1945 a total of $315,658,264 was spent on construction of CWS facilities.[31]

"The most critical problem of the whole war program was that of facilities expansion," said an Industrial College research study of 1947.[32] To win the war the munitions capacity of the country had to be increased tremendously and many of the same materials needed for munitions were also needed for facilities. The Executive Order establishing the War Production Board (WPB) placed the solution of the construction problem in the hands of that agency.[33] On 9 April 1942 WPB Order L-41 limited construction to facilities contributing to the war effort.[34] With the initiation of the Controlled Materials Plan (CMP) in November 1942 the following critical items were strictly rationed by the WPB: carbon and alloy steels, high octane gasoline, copper, aluminum, and nickel.[35] That this rationing had an adverse effect on the CWS construction and production program is evidenced by a complaint registered by the Chief, CWS, with the Commanding General, ASF, on 31 December 1942.[36]

While the complaint of the Chief, CWS, is understandable, for the War Department was obviously not giving priority to chemical warfare items, there was sound reasoning behind the War Department's action. Seven months after the date of the CWS complaint, the Director of Production Division, ASF, Brig. Gen. H. C. Minton, observed that it was War Department policy to operate many CWS projects at low rates and to maintain a large number of CWS facilities in standby. This policy, Minton said, was based on the character of chemical warfare to date. "Operations now and in the past," he stated, "have been only for the purpose of

[30] In 1942 construction was undertaken on the Kanawha Plant, South Charleston, W. Va., and the Maury Plant, Columbia, Tenn. In 1943 work was begun on the following plants: Seattle, at Seattle, Wash.; Marshall at New Martinsville, W. Va.; Owl at Azusa, Calif.; Firelands at Marion, Ohio; and Birmingham at Birmingham, Ala. The plants which were started in 1944 were the Duck River Plant, Columbia, Tenn.; and the San Bernardino Plant, San Bernardino, Calif. See Appendix A for details on all CWS facilities built in World War II.

[31] See app. B.

[32] ICAF R83, Construction of New Facilities, p. 63.

[33] E O 9024, 16 Jan 42.

[34] For discussion of effects of this order on construction in the Army, see Jesse A. Remington and Lenore Fine, Construction in the United States, a Corps of Engineers volume in preparation for the series UNITED STATES ARMY IN WORLD WAR II, ch. XIII.

[35] For discussion of CMP in CWS see below, pp. 281-82.

[36] Ltr, C CWS to CG ASF, 31 Dec 42, sub: Delayed Shipments of Equipment for CWS Program. CWS 400.226.

building up our base supply of materials for chemical warfare and the plant capacity must be maintained in token operation with trained crews ready to start full production at a moment's notice, should the enemy elect the use of chemicals. These plants are insurance against changes in warfare tactics." [37]

To administer expanding construction functions, the Chief, CWS, in May 1942 directed that a Construction Division be activated in the Industrial Service of his headquarters. This division, whose chief was Col. Lester W. Hurd, was charged with collecting data on construction and maintaining liaison with the Office of the Under Secretary of War, the General Staff, Headquarters, ASF, and the Corps of Engineers. As of 1 May 1942 the organization chart of the division listed its strength as ten officers and fifty-two civilians. In August 1942 the division was renamed a branch of the Industrial Division and because the Corps of Engineers maintained that construction of facilities was its function the name was changed to Facilities and Engineering Branch and later to Facilities and Requirements Branch.[38]

Matériel Shortages and Imbalances

The shortage of raw materials which arose in the emergency period became even more acute once war was declared. Until the end of 1942 the chief need for such materials was for construction facilities. From then until the close of hostilities the principal demand for raw materials was for production of munitions, which started to mount sharply once war was declared. Typical shortages in the CWS were steel for decontaminating apparatus, nickel-chrome steel for elevating screws for 4.2-inch mortars, Monel metal and stainless steel for valves for one-ton containers, and raw chemicals for protective ointment and smoke mixtures.[39]

The problem of shortages was complicated by the lack of an efficient system of overall administration for the country. The government first established the priorities system to control the flow of materials during the emergency period. Under this system ratings were assigned to end items.

[37] Memo, Dir Prod Div for the Dir of Materiel, 2 Aug 43, sub: Report on the War Department's Investment in Industrial Facilities. ASF 004 Facilities.

[38] (1) OC CWS Off O 40, 29 Jul 42. (2) Interv, Hist Off with Brig Gen Clifford L. Sayre, 18 Oct 56. Sayre, then a lieutenant colonel, was assigned to the Construction Division during World War II. (3) OC CWS Organization Charts, 6 Nov 42 and 10 Aug 43.

[39] See Reports of Accomplishments and Pending Difficulties in Connection with Procurement and Production Activities of CWS, prepared by Chief, Industrial Service, OC CWS for USW, 25 Feb, 5 Mar, and 9 Apr 42. CWS 400.12/106-139.

By the fall of 1941 this arrangement was supplemented by one of allocations which aimed at control of materials in the component stage.[40] Under the priorities system, the Office of Production Management examined the applications of prospective claimants, and notified producers to ship allotted quantities of critical items to those contractors whose applications were approved.

To supervise its priority and allocation activities, the CWS set up a separate section in the Procurement Planning Division, OC CWS, early in 1941.[41] This section had responsibility for estimating the amounts of critical materials needed and recommending priorities to be assigned to end items. The Chief, CWS, submitted these recommendations to the Army and Navy Munitions Board for assignment of certification of priorities. They were then passed on to the Office of Production Management for final approval.

With the great increase in the volume of contracts after the outbreak of war came a corresponding rise in priority and allocation activities. In the OC CWS the priorities unit was raised to the status of a branch—the Priorities and Allocation Branch—which remained one of the largest administrative units in the OC CWS during 1942 and early 1943.[42] For each contract entered into by the CWS, this branch drew up a schedule of every pound of critical material needed.

Notwithstanding that much time and effort were put into the compilation of these schedules the information did not always reflect the true situation. The reason was that the manufacturers made the same item in different ways (even though they used identical specifications). Consequently, some manufacturers consumed a much greater quantity of critical material than others. In view of the serious problem of scarcities, it was essential that the situation be corrected.

The solution adopted by the chief's office was to have bills of material drawn up which listed component parts of every item as well as the

[40] For details on material controls in World War II see: (1) Donald M. Nelson, *Arsenal of Democracy* (New York: Harcourt Brace, 1946); (2) Civilian Production Administration, *Industrial Mobilization for War; History of the War Production Board and Predecessor Agencies, 1940–1945* (Washington, 1947), vol. I, pp. 457–74; (3) Smith, *The Army and Economic Mobilization,* pt. VI, chs. XXII–XXVI; and (4) Millett, *Organization and Role of the Army Service Forces,* ch. XIV.

[41] This section was headed by a CWS Reserve officer called to active duty in January 1940, Capt. Alexander Leggin. Unless otherwise indicated this discussion of priorities and allocations is based on Interv, Hist Off with Leggin, 23 June 55.

[42] OC CWS Organization Chart, 6 Nov 42, lists 27 officers and 68 civilians in this branch. According to Leggin in his interview of 23 June 55, the numbers listed were very close to those actually employed.

exact time and quantity of critical material going into each item. General Porter decided to use recent graduates of the CWS Officer Candidate School on this project and other officers were borrowed from the procurement districts. In the summer of 1942 about 300 of these young officers were housed in a hotel owned by the Bata Shoe Co. near Edgewood, Md., where for six weeks, seven days a week, they worked hour after hour drawing up bills of material. As of 1 November a temporary freeze was imposed on drawings and specifications because the bills were subject to continual changes from waivers and changes in specifications. The freeze was lifted upon completion of an initial bill of material.[43]

The compilation of up-to-date bills of material was one of the most significant procurement developments of the war, for these bills enabled the service to determine the precise quantity of raw materials needed and where and how it was being used. The CWS could refer to them to iron out discrepancies between its figures and those submitted by contractors. The bills also aided in forecasting production more accurately since gross critical materials requirements could be exactly computed for scheduled delivery; they furnished data later required by the War Production Board and the Army Service Forces under the Controlled Materials Plan.

Defects inherent in the overall system of government priorities led to the inauguration of the CMP in late 1942.[44] The CMP provided for an allocation of critical materials to each service according to the national supply and according to the relative needs of that service. Under the CMP, priorities were no longer assigned to end items but to the critical materials. Since steel, copper, and aluminum were the most critical, these materials were the first to be included in the CMP. Later, other items such as rubber were added.

The Controlled Materials Plan was a far more orderly and equitable system than any that had preceded it. In the CWS the system worked extremely well, partly because the list of chemical warfare items was smaller than that of the other technical services, and partly because the CWS had already compiled accurate bills of materials. The CMP enabled

[43] (1) Interv, Hist Off with Col Lester W. Hurd, 18 Mar 57. (2) Conference, Commanding Officers, Chemical Warfare Districts, Industrial Division, OC CWS, 3–4 Mar 43, pp. 19–23. CWS 314.7 Procurement File.

[44] For details see (1) Smith, *The Army and Economic Mobilization*, ch. XXV and (2) Civilian Production Administration, *Industrial Mobilization for War*, vol. I, pt. IV, ch. VI. H. Duncan Hall, in "History of the Second World War," *North American Supply*, p. 386, note 1 (Longmans Green & Co., 1955), states that the U.S. Controlled Materials Plan was patterned after the British system.

the service to delegate priority and allocation responsibilities to its installations, with staff responsibility being retained in the chief's office. Unfortunately the system was inaugurated after the construction program had passed its peak and after the procurement of certain items was well advanced. But this was perhaps inevitable. The CMP was a system that grew out of the trials and errors of several years of procurement experiences and it is difficult to see how it could have been drawn up beforehand.

The Search for Suitable Contractors

The procurement of items through private contract, initiated in the CWS with the awarding of the first educational order contract in 1939, continued in 1940 and 1941 financed by appropriations in support of the Munitions Program of 1940. All educational order contracts and many of the other contracts were written in the Office of the Chief, CWS. Relatively few contracts of any kind were written in the district offices before December 1941 because the chief's office, as already indicated, had to approve all contracts exceeding $10,000. Actual entrance into war led to the immediate need for eliminating such a highly centralized procedure. Nine days after war was declared Under Secretary Patterson urged the chiefs of the technical services to expedite and decentralize war procurement. He directed them to award contracts without advertising and specified that only contracts in excess of five million dollars need be submitted to his office for approval.[45] On the very next day, 18 December, the First War Powers Act, vesting broad procurement powers in the Secretary of War, became law. One feature of this act was the decentralization of procurement activities to field offices; [46] another was the authorization of contracts through negotiation.

In pursuance of the First War Powers Act and of Executive Order 9001, 27 December 1941, which President Roosevelt issued to implement

[45] (1) Awarding of contracts without advertising, that is, by negotiation, was provided for in P.L. 703, 76th Congress and in Section 9 of the Military Appropriations Act of 1942. However, until 17 December 1941 the Under Secretary of War urged caution in the use of negotiated contracts. See Troyer S. Anderson, History of the Office of the USW (1914–1941), unpublished monograph, OCMH, ch. VI, p. 13. In the CWS there was a limited number of negotiated contracts prior to the declaration of war. Not till after the enactment of the First War Powers Act did negotiation become common. (2) Memo, USW for C CWS, *et al.*, 17 Dec 41, sub: Decentralization of Procurement. (3) Telg, USW to C CWS, *et al.*, 17 Dec 41. Both in USW 400.13 Procurement.

[46] The Secretary of War asked the Attorney General for an opinion on the constitutionality of his power to delegate authority to contract to field offices. The Attorney General ruled that he had such power. See Ltr, Att Gen to SW, 29 Aug 42. CWS 381.

the act, and in conformity with directives from the Under Secretary of War, the Chief, CWS, decentralized procurement activities to the field installations under his command in January and March 1942.[47] From then until the close of the hostilities CWS procured the bulk of its matériel through private contracts. The CWS arsenals and plants generally confined their activities to manufacturing chemical agents and to chemical warfare munitions which were difficult to obtain through private contract.

The hardships which the Chemical Warfare Service began to experience in obtaining suitable contractors in the emergency period became much more pronounced after the declaration of war. Since the Industrial Mobilization Plan of 1939 had not been put into operation, the CWS, as indicated, in some instances had lost allocated contractors to other elements of the armed forces, particularly the Ordnance Department and the Navy. This state of affairs continued into the war period. Only for the gas mask and raw chemicals did the CWS experience little difficulty in obtaining contractors with the necessary experience and equipment. Thanks to the educational order contracts on the mask, excellent contractors with well-equipped plants were already in production and were willing and able to proceed with other gas mask contracts. In the case of raw chemicals, a sizable number of well-established houses were available for government work. On all other items, CWS usually placed contracts with establishments that had not been allocated to it under the Industrial Mobilization Plan. In almost all instances these establishments were small operators who had to convert their plants in order to manufacture the items.

While the CWS was not in the most favorable position with regard to prospective contractors, the difficulties can be exaggerated. It is true that many of the contractors were small businessmen, but most CWS contracts were for components which small contractors were well able to handle. It is also true that the contractors had to convert their plants, but this would have been the case even with larger contractors since 95 percent of all CWS items were noncommercial.[48] Actually there was seldom any dearth of bidders for CWS contracts and generally when the contractors had gained experience they did an excellent job. A more serious problem than securing contractors and converting plants was the lack of

[47] (1) Ltr, C Ind Div OC CWS to COs PDs and Arsenals, 3 Jan 42, sub: Authority to Contract. CWS 400.12/105. (2) Ltr, C CWS to COs PDs and Arsenals, 23 Mar 42, sub: Approval of Awards and Formal Contracts. CWS 160/3011.

[48] CWS Presentation, SOS Staff Conference, Procurement and Production Problems, January 14, 1943, p. 2. CWS 337, 1943.

proper specifications for the contractors. As already indicated, the CWS drew up specifications during the peacetime period, but in some instances these were of little value when the items had to be produced under assembly line procedures. Moreover, time did not permit the development of complete specifications on the important items for which the CWS was given definite procurement responsibility in the emergency period—the 4.2-inch mortar and shell, the incendiary bomb, and the flame thrower. These and other items the CWS, and in some cases the contractors, continued to develop after the service had awarded production contracts on the items. Since much of the matériel produced under the early contracts soon became obsolete, much time and money were lost. It would have been to the advantage of the government, from the standpoint of both economy and preparedness, if in the 1930's the CWS had been allowed to expend on the development and engineering of munitions a fraction of the funds that were allocated after Pearl Harbor.

The Chemical Warfare Service had already been placing contracts with small business firms over a period of months when the Small Business Act was passed in June 1942.[49] To administer that act the ASF set up a Small War Plants Branch in its purchases division, and shortly thereafter the technical services appointed liaison officers in their headquarters and field installations. These officers were in constant touch with the representatives of the Smaller War Plants Corp. (SWPC) which was set up under the act.[50]

The CWS soon acquired something of a reputation in the War Department for awarding contracts to smaller war plants and for assisting the small fellow generally.[51] When General Somervell's office conducted surveys in New York and Cincinnati in 1942, for instance, it found that the CWS through its New York district office would call in manufacturers to help delinquent contractors straighten out their difficulties.[52] In the fall of 1942 a witness before the Small Business Committee of the United States

[49] P.L. 603, 77th Cong, 11 Jun 42.

[50] Appraisals of the SWPC are contained in the following lectures given at the Army Industrial College: W. D. Denit, War Production in Small Plants, 13 Dec 46, ICAF L47-54; B. T. Bonnot, Problems of Small War Plants in Industrial Mobilization, 28 Mar 46, ICAF L46-61; and R. C. Enos, Utilization of Smaller Plants, 23 Mar 49, ICAF L49-108. All in ICAF Library.

[51] (1) See Chart 7, ASF Annual Report 1943, p. 31. (2) Remarks of Brig Gen P. X. English, Conference of Commanding Officers, CW Procurement Districts, 3-4 Mar 43, p. 114. CWS 314.7 Procurement File. (3) Ltr, CO NYCWPD to C CWS, 16 Oct 42, sub: Local Newspaper Reports on Small War Plants. CWS 000.7.

[52] See Harry B. Yoshpe, Organization for Production Control in World War II, 1939-45, *passim.* An unpublished monograph in OCMH.

Senate stated that the only government agency in New York in which there was any "real co-operation" and "any degree of efficiency" so far as procurement work was concerned was the CWS. "The manufacturer," the witness stated, "may go to the Office of Chemical Warfare, bring his brochure, his financial statement, a line of his material and equipment, and within a short time an engineer will go out from Chemical Warfare to inspect the plant, to determine whether or not it is available for present war work or can be converted into war work." [53]

The award of numerous contracts to smaller businesses was not without its drawbacks. Most small contractors lacked facilities for volume production of standard or specialized parts and had to let subcontracts to smaller firms for such parts. Again, while the small prime contractors were often purchasers of standard commercial raw materials, the volume of their business did not warrant maintaining skilled purchasing departments capable of contracting for made-to-order components on the scale called for under war contracts. Moreover, government inspection methods were almost completely foreign to the commercial experience of the smaller companies. All these factors complicated the job of the CWS procurement officer, who had to provide administrative, technical, and engineering assistance to a number of contractors who could not afford to hire men trained in these various fields. The CWS procurement officers, both in the chief's office and the installations, were generally Reserve officers with engineering education and some experience in industry. Without the assistance of these men the service could not have carried out its procurement mission.

Particularly burdensome, from the point of view of administration, was the practice of awarding numerous contracts for components to small war plants. This practice entailed a tremendous amount of administrative work both in the chief's office and in the procurement districts. Although the system worked fairly well during the first year of the war, by the spring of 1943 a definite change was indicated, for by then General Somervell's office was emphasizing controls of all sorts, including control of manpower and control of production. The matter came up for serious discussion in the conference of CWS procurement officers in March 1943.[54] By

[53] Hearings before the Special Committee to Study and Survey Problems of Small Business Enterprises, U.S. Senate, 77th Cong, 2d Sess, Pursuant to S.R. 298 (76th Cong); Part 10, Small Concerns in War Production: I–Oct 13, 14, and 15, 1942.

[54] Conference of Commanding Officers, CW Procurement Districts, 3–4 Mar 43, *passim.* CWS 314.7 Procurement File.

the fall of 1943 the CWS had worked out a new system of procurement which emphasized end-item buying rather than component buying. Contracting officers were urged to make end-item contractors responsible for the procurement of their own components. The end-item contracting system was not immediately successful in all cases since some contractors were reluctant to undertake responsibility for subcontracts or were unable to find subcontractors.[55] But despite its defects, end-item buying was one of the most important administrative developments in the CWS during World War II.

Inspection of Matériel

After the outbreak of hostilities the number of inspectors rapidly increased. They were needed not only in the existing installations but also in those newly activated—Pine Bluff, Huntsville, and Rocky Mountain Arsenals, and Atlanta and Dallas Procurement Districts. By the close of 1942 the CWS reached its peak wartime figure of 6,398 inspectors. From then until the end of the war the number dropped sharply—less than 3,000 in December 1943 and less than 2,500 in May 1945.[56]

The training and experience requirements of CWS inspectors varied with the type of positions they had to fill. Those in key posts had to have technical training and were expected to have a college degree or its equivalent, particularly if they were engaged in inspecting chemicals. Line inspectors were required to have a high school education, be intelligent, and be willing to learn. As the war went on, women were hired in great numbers as line inspectors. In general their performance was equal to that of the men and many women were advanced to supervisory positions, even to that of chief inspector. However, it was difficult to find women with the necessary formal education and practical experience required for key positions, and these were generally filled by men.

The chief reason for the great number of inspectors in 1942 was the prevailing practice of inspecting end items and components on a 100 percent basis. Despite this practice inferior chemical warfare munitions were being sent to installations in the zone of interior and to the theaters.[57]

[55] Intervs, Hist Off with Cols Almon N. Bowes and A. J. L. Wilson, 27 Nov 56. Colonels Bowes and Wilson were officers in the New York Procurement District in World War II.

[56] (1) Analysis of Operations of the Inspection Division, 1942–1945, compiled by Col John H. Sharp, C Insp Div, OC CWS. (2) Ltr, C Insp Div OC CWS to Chiefs, Inspection Offices, all districts and arsenals, 3 May 45, sub: Policy of Inspection Division on Manpower Utilization and Other Studies. Both in CWS 314.7 Inspection File.

[57] (1) Ltr, CG CWS Repl Tng Center, Camp Sibert to C CWS, 7 May 43, sub: Report of Inspection Trip. CWS 319.1. (2) Ltr, Maj D. Althauser to C Tech Div, OC CWS, 13 May 43, sub: Report on Tour of Temporary Duty in ETOUSA and NATOUSA. CWS 381.

The Chief, CWS, felt that before any real improvement in inspection procedures could be effected, some changes would have to be made in the organization of his office and the installations. Until May 1943 the Inspection Branch of the chief's office was an element of the Industrial Division. The inspection units at the installations reported to the division's commanding officers, whose chief objective in accordance with War Department policy in 1942 and early 1943 was to procure more and more of everything with the greatest possible speed. To solve the problem of inferior inspection the Chief, CWS, in the reorganization of his office on 27 May 1943, made the inspection unit independent of the procurement unit by putting the Inspection Division on the same echelon as the Industrial Division.[58] At the same time he directed that the inspection units at the installations be put under the direct jurisdiction of the Inspection Division, OC CWS. While commanding officers of some installations later questioned the wisdom of this action, none ever expressed doubt that from May 1943 until the end of the war a great improvement took place in the quality of CWS items.[59]

The CWS's first step to improve inspection procedures after the 27 May 1943 reorganization was the elimination of inspection of components. On 4 August 1943 the Assistant Chief, CWS, for Materiel, announced that henceforth all contracts would contain a clause to the effect that the contractor would be responsible for such inspection.[60] After this policy was announced a number of former CWS inspectors were hired by the contractors to carry out the same work they had done for the government.

A second step toward improved administration of inspection was the inauguration of the practice of accepting chemical components on the basis of notarized certificates of analysis submitted by the contractor. Under this procedure the duties of the CWS inspector were confined to making spot checks of the material.[61]

A third move in the direction of improved inspection was the introduction of a system of statistical quality control. As early as the fall of 1942 the CWS became interested in this type of inspection as carried out by such industrial concerns as the General Electric Co. and the American

[58] (1) OC CWS Off O 39, 27 May 43. (2) Chiefs of Inspection Division in World War II were Maj. John L. Miles, Maj. Elwood H. Snider, Lt. Col. Ludlow King, Col. William M. Creasy, and Col. John Sharp.

[59] Brophy and Fisher, *Organizing for War*, ch. VI.

[60] Ltr, AC CWS for Matl to Chief Inspection Officers, all Districts and Arsenals, 4 Aug 43, sub: Personnel Reductions. CWS 314.7 Inspection File.

[61] This procedure is discussed in ASF Manual CWS-M608, 1 Sep 44, par. 712.

Telephone and Telegraph Co. The system was mathematical in nature, embodying the sample inspection of a fixed number of items from each lot produced. The number of items selected from a lot was based on records of past performance. Little headway was made in the CWS with statistical quality control until Headquarters, ASF, directed the service to draw up and adopt tables based on the "laws of probability reconciled with results of actual experience." [62] From the fall of 1943 until the close of the war the CWS inaugurated the system on a gradual basis. Although the project involved considerable planning and retraining of personnel, the results obtained more than justified the time and effort expended. By properly applying the principles of quality control, Inspection Division, OC CWS, was able to greatly improve inspection and at the same time reduce the number of inspectors. To take but a single example, after the Quality Control System was established the number of inspectors on the M50 bomb program was reduced from 66 to 35.[63]

Another significant administrative innovation was the centralization of the control of waivers. A waiver, as the term implied, dispensed with a particular requirement of a drawing or specification. It permitted a variation in the standard of quality, but not to the extent of causing a deterioration in the product. Waivers were intended to apply only to a minimum quantity over a particular period of time. Their issuance was a perfectly legitimate procedure so long as the practice was not abused. But unfortunately the practice was abused, and it became necessary for the Inspection Division, OC CWS, to revise procedures on issuance of waivers. In June 1943 the Assistant Chief, CWS, for Materiel, issued a directive that districts and arsenals could grant waivers only with the concurrence of the Chief, Inspection Division, OC CWS. The Inspection Division was to use its discretion in obtaining the concurrence of the Technical Division. In all instances the Chief, Inspection Division, was to notify the Industrial Liaison Branch, which would in turn notify the installation.[64]

Other important measures taken to improve inspection were the use of standardized gauges throughout the CWS, standardization of procedures for operating CWS inspection laboratories, an adequate system of surveillance, and the compilation of an inventory of items in CWS depots.

[62] See ASF Manual CWS-M608, 1 Sep 44, par. 1022.

[63] History of New York CWPD 1940 through June 1944, pp. 268-69.

[64] (1) Ltr, AC CWS to C Ind Div, *et al.,* 29 Jun 43, sub: Directives Governing Definitions and Procedures on Waivers, Alternates and Changes. CWS 400.1141 1943. (2) ASF Manual CWS-M608, 1 Sep 44, par. 1040. The Industrial Liaison Branch was responsible for clearance of drawings and specifications as well as waivers. See OC CWS Adm O 14, 7 Aug 43.

In 1943 the Specification and Inspection Branch, ASF, contracted with the Trundle Engineering Co. of Cleveland to survey inspection practices in the technical services. The report of this survey, which was turned over to the Director of Production, ASF, on 2 July 1943, indicated that the CWS was outstanding among the technical services with regard to inspection organization and procedures.[65] One of the most significant results of the Trundle survey was the formulation by the War Department of general inspection policies, which were eventually published in ASF Inspection Manual M608, in March 1944. This manual was to be implemented by inspection manuals in the technical services, with CWS Inspection Manual M608 not published until 1 September 1944.

Inspection manuals were exteremly useful in keeping the inspectors informed on government policies and procedures, but they were not intended to serve as guides for individual inspectors working on specific items. For that purpose the Inspection Division, OC CWS, prepared individual standard inspection procedures. A standard inspection procedure described the item, specified the parts to be inspected and the tools or instruments needed to accomplish the inspection, and finally, indicated where pertinent how the item would be proof tested, inspected for surveillance, and packaged.

Inspection in the CWS improved so markedly after the independent Inspection Division was set up in the chief's office in May 1943, that the action stands out as one of the wisest organizational moves of the wartime period in the CWS. Not only did the quality of inspection improve; the attitude of the inspectors took a marked turn for the better. For, once they were removed from the control of those who at OC CWS level were responsible for meeting production schedules, the inspectors carried out their duties in a more effective manner.

The Pricing Program

The Second War Powers Act, supplemented by Presidential order, authorized certain government agencies, including the War Department, to inspect and audit the books of war contractors and subcontractors.[66] The War Department established administrative units for securing voluntary adjustments or refunds whenever prices, costs, or profits were considered

[65] Report of Inspection Survey for Inspection Section, Facilities and Inspection Branch, Production Division, Headquarters, ASF, by the Trundle Engineering Co. CWS 314.7 Inspection File.

[66] (1) 56 *Stat* 176, 27 Mar 42. (2) EO 9127, 10 April 1942.

excessive. In the CWS, for example, a Price Adjustment Section was activated in the Legal Branch on 8 August 1942.[67] Later a Cost Analysis Branch was set up in the Fiscal Division to collect data on costs and profits on War Department contracts.[68] Close liaison was maintained between the fiscal and legal officers on all matters pertaining to costs.[69]

The enactment of renegotiation legislation in 1942 and 1943 led to greater emphasis on pricing analysis in the War Department.[70] In one of the Procurement Regulations which the War Department began to issue in the spring of 1943 provision was made for a revision of pricing organization and procedures.[71] In conformity with this regulation, Headquarters, ASF, established a Purchases Division and the technical services activated similar units at their headquarters.[72] In the CWS the unit was known as the Purchase Policies Branch.[73] Throughout the war it was headed by Lt. Col. Robert M. Estes. In September 1943 the branch was transferred from the Washington headquarters to the Baltimore suboffice of the Chief, CWS, where it remained for the duration of the war.

The chief of the new Purchase Policies Branch faced the problem of attempting to carry out the provisions of an act that was not popular either with the contractors or with CWS contracting officers. Each group felt that price analysis tended to interfere with production, their principal mission. If the law was to be carried out in letter and in spirit, this prejudice against pricing activities had to be overcome.

[67] OC CWS Off O 44, 8 Aug 42.

[68] OC CWS Organ Chart, 22 Feb 43.

[69] Interv, Hist Off with Lt Col Joseph F. Escude, 25 Jun 46. Colonel Escude served with the Fiscal Division throughout World War II.

[70] Renegotiation was provided for in Section 403 of the Sixth Supplemental National Defense Act as amended in October 1942 and again in Title VIII Section 801 of the Revenue Act of 1943. The 1943 act modified the 1942 act in the following particulars: (1) The 1942 act vested administrative authority in the Secretaries of the Departments, whereas the 1943 act set up an interdepartmental War Contracts Price Adjustment Board. (2) The 1942 act did not provide for court action; the 1943 act made provision for determination by the Tax Court of the United States. (3) The 1942 act covered renegotiation and repricing in the same statutory provision, while the 1943 act treated the two separately and vested the repricing power in the Secretaries of Departments. (4) The 1942 act provided for exemptions measured by sales volume under war contracts up to $100,000; the 1943 act set the figure at $500,000. (5) The 1942 act set the date of discontinuance of renegotiation as three years after the war; the 1943 act set the date as 31 December 1945. (6) The 1943 act was more specific as to exemptions from renegotiation procedures and methods of determining excess profits.

[71] WD Procurement Regulation 2, 26 Mar 43, sec V.

[72] See Smith, *The Army and Economic Mobilization,* pp. 273–79, for a discussion of wartime pricing policy. The chief objective behind the WD pricing program was to compel contractors to produce efficiently if they wished to make a profit. To produce efficiently they would have to make effective use of manpower, materials, and equipment.

[73] OC CWS Off O 31, 1 May 43.

LT. COL. ROBERT M. ESTES

The first step which the Purchase Policies Branch took was to secure the co-operation and obtain the support of the procurement district staff. A survey of the districts conducted by the branch in the fall of 1943 revealed an almost total lack of interest and initiative with regard to pricing functions.[74] To rectify this situation General Ditto, Assistant Chief, CWS, for Materiel, wrote a letter in December 1943 to the commanding officers of the districts in which he emphasized that price analysis was primarily a district function.[75] From then until the close of the war the procurement districts were more active in conducting pricing operations. The Purchase Policies Branch, OC CWS, continued to act in a staff capacity on all pricing matters.

The co-operation of the district officials was secured not alone by directive from the chief's office, but also through demonstration of the practical utility of pricing studies. One of the principal means of convincing contracting officers of the value of such studies was the dissemination of comparative price and cost data throughout all CWS procurement installations. From January 1944 on, the Purchase Policies Branch distributed copies of the price reports covering the most important (from the standpoint of cost) chemical warfare items of procurement on a weekly basis. Each installation was thus advised of every change in the unit price or cost of important CW items. Price analysts in the districts compiled the data on index cards for ready reference. Another method whereby increased interest in pricing was fostered was through conferences of all CWS purchase policy personnel.

Opposition on the part of contractors was considerably mollified by the threat of prolonged renegotiation of their contracts. For while a great

[74] Analysis of CWS Pricing Record in World War II, p. 18. This 100-page mimeographed report was compiled by Purchase Policies Branch OC CWS in 1945. MS in Hist Off.
[75] Ltr, AC CWS for Matl to CO CCWPD, *et al.*, 3 Dec 43, sub: Relationship of Price Analysis to Procurement. CWS 400.12.

many contractors disliked the inconvenience caused by price and cost analysis, they thoroughly detested renegotiation, which they conceived of as both un-American and unconstitutional.[76] During 1943 a number of businessmen testified in Congressional hearings before four separate committees that in their opinion government contracting officers should have sufficient information to draw up contracts which guaranteed that no excess profits would be made and thus do away with the need for renegotiation. After this testimony, the President ruled that by June 1944 the need for renegotiation of contracts should have been eliminated. The War Department thereupon put considerable pressure on the technical services to improve their knowledge and handling of all aspects of purchase policies. The June 1944 deadline was not met and renegotiation activities were still being carried on when the war ended. This deadline, however, plus the continued uncertainty over whether Congress would continue renegotiation legislation, acted as incentives to sound pricing policies in the CWS.[77]

In the spring of 1944 the Purchase Policies Branch brought about a significant improvement in price analysis techniques by adding to its staff a qualified industrial engineer and an accountant experienced in production cost procedures. The branch required the services of the engineer to evaluate different drawings and specifications and to act in an advisory capacity to the accountant and other pricing personnel.[78] In July 1945 the Chief, Industrial Division, OC CWS, recommended that the services of industrial engineers be utilized also in pricing operations in the districts, but the war came to an end before this suggestion was acted on.[79]

The fact that very few chemical warfare items were manufactured in peacetime made it generally impossible to establish equitable prices at the start of the war. In the emergency and early wartime period, the CWS wrote contracts for most items without too much regard to price. Assistant Secretary Patterson himself urged the chiefs of the technical services not to be too concerned about prices, but rather to see that the supplies for the troops were delivered on time. Excess profits, he said, could be recaptured through legislation.[80]

[76] (1) Analysis of CWS Pricing Record, p. 11. (2) Smith, *The Army and Economic Mobilization*, p. 354.

[77] Remarks of Lt Col R. M. Estes, Report of CWS Procurement Conference held at Pittsburgh, Pa., 8 Jan 45. CWS 314.7 Procurement File.

[78] Analysis of CWS Pricing Record, p. 21.

[79] Ltr, C Ind Div OC CWS to CO NYCWPD, 5 Jul 45, sub: Industrial Engineer to Assist in Price Analysis. CWS 213 NYCWPD (1945).

[80] Interv, Hist Off with Maj Gen W. N. Porter (Ret), 14 Sep 51.

The only major item on which the CWS had cost and price data was the gas mask because that was the one item which continued to be manufactured in considerable quantity after World War I. Experience gained under the educational order contracts was especially productive of valuable data on the cost of the mask. The Purchase Policies Branch had little trouble, therefore, compiling charts depicting the discrepancies in prices charged by the various contracts. By simply calling the attention of the contractors to these charts it was sometimes possible to secure a reduction in prices. The price level of the gas mask declined over 9 percent between January 1942 and June 1945.[81]

Contractors on other CW items, lacking as they were in experience, often quoted prices which were later considered exorbitant. It was almost inevitable that the initial cost of production would be high, because the manufacturer first had to learn how to produce the item. After he mastered that, he learned how to make it more economically. In most instances the manufacturers gave the government the benefit of their ability to produce at lower cost by voluntarily reducing their prices. Those who co-operated with the government received preferential treatment under the Renegotiation Act.[82] Those who did not were thoroughly checked not only by the War Department but by the General Accounting Office. As of February 1945 the CWS was investigating some twenty companies whose profits exceeded 15 percent or whose profits in renegotiation had been cut by 25 percent.[83]

Pricing operations, as noted, were always simplified when a number of contractors worked on the same item. As in the case of the mask, it was possible to make comparisons between the prices charged by the various manufacturers and on that basis to attempt price adjustments. Practically all items manufactured by the CWS followed the competitive pattern. Although originally a single manufacturer might have been awarded a contract, eventually several competing firms were also given contracts and the prices of all were subject to study. In the case of the portable flame

[81] Analysis of CWS Pricing Record, p. 39.

[82] Testimony of George H. Knutson, member of the War Department Price Adjustment Board, in Hearings before Special Committee Investigating National Defense Program, Part 34, pp. 17988-18008 (Washington, 1946). The War Department Price Adjustment Board became a staff division of ASF in the fall of 1943.

[83] Remarks of Lt Col R. M. Estes, Report of CWS Procurement Conference held at Dallas, Texas, 14-15 Feb 45. CWS 337 Dallas PD 1945. The CWS was carrying on its investigation under an ASF program known as "Company Pricing," initiated under ASF Cir 207, 1944. See Smith, *The Army and Economic Mobilization,* 339-50, for details on this program.

thrower, for example, the Kincaid Manufacturing Co. of New York City early in 1941 was assigned the job of developing a flame thrower. By the time this contract was completed the E. C. Brown Co. of Rochester, N.Y., was called on to manufacture the item. Later two other companies, the Beattie Manufacturing Co. of Little Falls, N.J., and R. F. Sedgley, Inc., of Philadelphia were also awarded similar contracts. A comparison of the prices charged by these contractors enabled the CWS to effect reductions. These price reductions amounted to over 27 percent for the period of the war.[84]

While most CW items were manufactured by a number of contractors, there were occasional exceptions. For example, the barrel of the M1A1 and the later M2 chemical mortar was made exclusively by the Bell Machine Co. of Oshkosh, Wis., which also assembled the mortar. It was not possible, therefore, for the CWS Purchase Policies staff to make comparative studies of prices and costs of this item. On its own initiative the Bell Machine Co. reduced prices and made large refunds to the government in the period 1942–45. Acknowledging that the attitude of the contractor was commendable, the chief of the Purchase Policies Branch felt that completely accurate cost data could not be obtained unless the company installed an adequate cost accounting system. The company readily accepted this suggestion and it further agreed to co-operate with CWS engineers and accountants who went to its plant in the spring of 1945 to conduct an extensive study of costs. As a result of the CWS study, the Bell Machine Co. voluntarily reduced its prices once more, from $724.30 to $575.00 per unit on one contract and from $649.30 to $575.00 per unit on another.[85]

CWS experience with pricing chemicals dated from the emergency period, when, as has been indicated, unprecedented demands arose for certain components of the incendiary bomb, including thermite. Thermite was manufactured in relatively small quantities in peacetime, and it sold on the open market for twenty-eight cents a pound. In the fall of 1941 the commanding officer of the New York Procurement District conducted an investigation into the price at which the chemical could be manufactured profitably on a large scale. With the assistance of a chemical broker and two officers with accounting background, he learned that something

[84] Analysis of CWS Pricing Record, pp. 89–92. See ch. XV below for details on the procurement of flame throwers and other weapons.

[85] Ltr, Pres Bell Machine Co to C CWS, 26 May 45. Reproduced in Analysis of CWS Pricing Activities, pp. 55–58.

in the neighborhood of eight cents a pound would be a reasonable price. He then made arrangements with certain ceramic manufacturers, whose plants were idle because of WPB restrictions, to produce the thermite at eight cents a pound or less.[86] This was the start of a campaign carried on throughout the war period to secure chemicals at a reasonable price to the government, a campaign that between January 1942 and May 1945 led to a reduction of 20 percent in the price of chemicals.[87] This figure compared favorably to the overall price reduction of 22 percent for all CW items and components from 1 January 1942 through 15 August 1945.[88]

The activity of the Chemical Commodity Division in effecting a reduction in prices is well illustrated in the case of napalm.[89] By the spring of 1944 seven contractors throughout the United States were producing this material at prices which varied as much as ten cents a pound. Upon investigation the Chemical Commodity Division discovered that the low cost producers were invariably those who had installed up-to-date labor saving equipment. The division representatives thereupon made arrangements to have such equipment adopted by other manufacturers. This action resulted in a general leveling off in the prices of the various manufacturers.[90]

Some of the problems the service and its contractors faced were common to all military procurement. These included the shortage of raw materials and machine tools, frequent changes in production schedules, and difficulty in obtaining and training competent workers for arsenal and depot operations. But the CWS generally found these problems more complicated because of the low priority which the War Department placed on chemical warfare items and because the CWS lacked experience in the manufacture of every item except the gas mask.

In carrying out its vast and varied procurement program in the early war years, the CWS made notable advances, particularly in compiling up-to-date bills of material and in inaugurating an improved system of inspection and a sound pricing program. Impressive as this record was there was still considerable room for improvement. But before improvement could be made, a drastic change had to be brought about in Army think-

[86] Interv, Hist Off with Col S. N. Cummings, 14 Sep 51.
[87] WD Monthly Progress Report, Section 1D, 3 May 45.
[88] Analysis of CWS Pricing Record, Introduction.
[89] For details on procurement of napalm see ch. XVI below.
[90] (1) History of Chemical Commodity Procurement, 1 Aug 44–13 Nov 45, p. 67. (2) Interv, Hist Off 10 Jun 58 with following former members of the Chemical Commodity Div: Walter C. Gibbons, Jerome F. McGinty, Robert J. Milano, and Benjamin M. Redmerski.

ing with regard to supply. A basic defect was the tendency to treat the main facets of supply—procurement and distribution—as separate entities. During the second half of World War II the Army initiated a program aimed at correcting the situation, a program whose main objective was the balancing of procurement and distribution.

CHAPTER XIII

Balancing Procurement and Distribution

Developments of the Early War Years

During the early part of the war when the Army was placing great emphasis on mobilizing men and matériel, CWS officers engaged in operations had little opportunity to concentrate on administrative improvements. Many of them both in the Washington headquarters and in the installations were working fourteen or more hours a day, with certain headquarters divisions running two shifts of civilian clerks. Some officers set up cots in their offices and seldom went home. Since most supervisory energies were absorbed in mobilization operations, the development of up-to-date administrative procedures lagged far behind. To more rapidly bring about greater efficiency, General Somervell, the commanding general of the ASF, directed the various elements of his command to set up units, known as control divisions or branches, whose chief function was to conduct surveys and studies aimed at administrative betterment.

The principal managerial deficiency throughout the supply system was a lack of co-ordination between the demonstrated needs of the troops in the field and the capacities of the procurement and distribution systems. To provide the necessary co-ordination, officials would have to root out inefficiency and waste, those inevitable products of mobilization haste. They could achieve this objective only by acquiring and analyzing comprehensive and accurate information on field requirements and on the actual operation of the supply system. At the beginning of the war planners did not have the experience to determine even what kind of information they needed. As they gained that experience, the principal problem was to evolve reporting and co-ordinating procedures which would make it useful.

The Control Division of the chief's office and similar units within the installations attacked this problem and did much to establish more business-like procedures throughout the CWS. Co-operating closely with the Control Division, OC CWS, was the competent staff of the Industrial Service (in July 1942 it was renamed the Industrial Division).

One of the Office of the Chief's earliest administrative studies was aimed at eliminating excessive paper work throughout the CWS. In the summer of 1942 the Administration and Management Branch, Control Division, in conjunction with the Executive Office, Industrial Division, made a survey of the forms and records maintained in the Washington headquarters and at the installations. They found that the installations had independently developed their own forms, 90 percent of which could have been eliminated without loss of efficiency, and that there was a staggering duplication of records between the chief's office and the installations.[1] Yet, despite all the record keeping, or probably because of it, no one in the CWS could tell just what was in the supply system. What was needed was an improved method of statistical control.

This need became all the more urgent after the ASF began to compile monthly progress reports on procurement and supply. In gathering information for these reports, Headquarters, ASF, requested accurate data from the various technical services on the quantity of items: (1) to be produced; (2) actually produced; (3) on hand at points of procurement; (4) en route to depots; (5) received at depots; (6) in storage at depots; and (7) issued by depots. In the fall of 1942 the Chief, CWS, charged the Control Division with developing an accurate system of statistical reporting. He assigned responsibility for carrying out the work to a financial statistician commissioned from civilian life, Maj. Philip J. FitzGerald of the Statistics and Progress Branch of Control Division.

FitzGerald first undertook to draw up an accurate definition of a procured item. The CWS installations and contractors were employing a variety of criteria for determining when an item was actually procured. For example, certain munitions were said to have been procured before they had been proof tested—and it sometimes took weeks for them to be tested—while others were not considered procured until after they had been proof tested. In most instances end items were considered procured only after all components had been assembled. But some items were defined as procured even though all components had not been assembled into the end product. FitzGerald, upon investigation, determined that the

[1] OC CWS, Activities of Control Division for Period 15 Nov 42 to 31 Dec 43, p. 12a.

OFFICER PERSONNEL OF THE CONTROL DIVISION. *From left: 1st Lt. Selig J. Levitan, Maj. Philip J. FitzGerald, Lt. Col. Llewellyn G. Ludwig, Colonel Kuhn, Lt. Col. Jacob K. Javits, Maj. Edward Mery, Capt. Lyman C. Duncan, and 1st Lt. James J. Troy.*

only sound criterion for describing an article as procured was the delivery of the "tally-in" by the Inspection Division to the Finance Office. This unique document not only described the article as combat worthy, but also established the CWS's financial responsibility for the item. The Statistics and Progress Branch pointed out to the Industrial and Inspection Divisions, OC CWS, the desirability of reporting all procurement from CWS installations on the sole basis of tally-ins and by early 1943 this was accepted practice. From then on the CWS could accurately compare production forecast with production accomplished.[2]

By the summer of 1943 the Supply Division, OC CWS, was receiving copies of War Department Shipping Documents which accompanied all shipments of materials. On the basis of these documents the CWS for the first time compiled accurate statistics on matériel shipped to the ports of embarkation and other points in the zone of interior. With these figures, together with those on procurement, the CWS could calculate the amount of matériel in transit, the amount received in depots, and the amount shipped directly to the various units.

[2] Interv, Hist Off with Col Philip J. FitzGerald, 10 Oct 56 and Ltr, FitzGerald to Hist Off, 8 Feb 57.

In mid-1943 General Porter set up a "Situation Room" in his headquarters where a representative of the Control Division, usually Major FitzGerald, briefed the chief and his staff on the data to appear in the monthly progress report. This procedure led the chief's office to a greater awareness of the procurement and supply problems of the CWS and to closer co-operation by those responsible for supervising procurement and those responsible for supervising the storage and issue of matériel.[3]

The surveys which the Control Division, OC CWS, conducted throughout 1942 and 1943 indicated an excessive degree of centralization in the Washington headquarters. This centralization was due in part to lack of standardized procedures and organizations throughout the CWS installations. By the summer of 1943 the latter condition had been largely corrected,[4] and it then became possible to decentralize many activities to the installations. The Central Planning Section, Industrial Division, OC CWS, headed by Lt. Col. Stanton D. Sanson, took the lead in the project. In the summer and fall of 1943 this section, in co-operation with the Control Division, OC CWS, and the commanding officers of the installations, drew up a decentralization plan which they labeled the 1944 Procurement Plan.

Under the new plan the Industrial Division, OC CWS, assumed the role of a staff rather than an operating agency. It prepared procurement schedules of end items for the installations, based on the Army Supply Program. In preparing these schedules the division consulted frequently with installation officials. Three weeks after the schedules were drawn up, a meeting of representatives of the chief's office, the arsenals, and the districts was held in Washington for the purpose of arranging the manufacture and delivery of components which the installations could not procure within their own confines.

Under the 1944 Procurement Plan the chief's office was no longer responsible for furnishing each installation with needed components; instead the districts and the arsenals dealt directly with one another, and the installation with whom the order had been placed was held responsible for delivery. Each installation was to procure its own components whenever possible. Each installation, moreover, was urged to write contracts for end items only, leaving the procurement of components to the prime contractor.[5]

[3] Activities of the Control Division 15 Nov 42–31 Dec 42, p. 21.

[4] Brophy and Fisher, *Organizing for War*, ch. VI.

[5] Chemical Warfare Service Procurement Plan for 1944 Procurement, 12 Aug 43. CWS 314.7 Procurement File.

The new plan was received enthusiastically by key officers in most installations. Typical of reactions to it were the remarks of the officer in charge of arsenal operations at Pine Bluff Arsenal, Col. H. M. Black:

> The added responsibilities given to the Arsenals and Procurement Districts, in that they alone are responsible for controlling and maintaining adequate stock positions of all direct materials required for the production of CWS end-items, had tended to bring the Arsenals and Procurement Districts closer together for better co-operation. Services and requests for services are exchanged much more freely. At no time previously has the general stock position at this Arsenal on all raw materials been in such favorable condition, and this Arsenal feels that with the privileges allowed in the plan, this condition can be perpetuated.[6]

While the Industrial Division was devising improved procurement procedures, the Supply Division, OC CWS, was developing a better system of distribution. In the early war period the Supply Division had issued matériel on the basis of notices of availability from production sources, routing the matériel to the storage facility nearest the manufacturer. While this practice made for a certain degree of convenience, the matériel later often had to be reshipped. Supply Division would frequently discover that depot A, to which the item had been sent, had a surplus of the item while depot B, more distant from the original point of procurement, had a deficit; the resulting reshipment, or "back hauling," from depot A to depot B was considerably more costly of scarce transportation and handling services than original shipment to the more distant depot would have been. After the Industrial Division, in mid-1943, came up with more accurate production forecasts, the Supply Division began planning distribution of newly procured items on the basis of those forecasts rather than on notices of availability. The result was a great decrease in the number of back hauls. A second innovation that led to a decline in the number of back hauls was the practice of correlating the stock levels of the depots with the troop basis of the particular theater that the depot served.[7]

Another malpractice that plagued the CWS distribution system in the early war period was cross hauling. A cross haul took place when a load of a specific item passed another load going in the opposite direction. A flagrant instance of cross hauling in the spring of 1944 led the Supply Division to take vigorous steps to eliminate the practice. Huntsville Arsenal had requested some 4.2-inch shells filled with HE for demonstration

[6] Ltr, CO PBA to C CWS Attn: C Ind Div, 10 Mar 44, sub: Comments on Effectiveness of 1944 Procurement Plan. CWS 400.12.

[7] Interv, Hist Off with William Harris, II, 29 Aug 57. Harris was a key officer in Supply Division, OC CWS, from May 43 until after close of World War II.

EXECUTIVE BRANCH OF THE INDUSTRIAL DIVISION. *From left: Lt. Joel O. Henry, Maj. Henry G. Baker, Jr., Lt. Col. Robert T. Norman, Col. Clarence W. Crowell, General English, Col. Lester W. Hurd, Lt. Col. Louis W. Munchmeyer, Maj. Stanton D. Sanson, Lt. Edgar St. Clair.*

purposes. Upon receiving the request the Supply Division, OC CWS, telephoned Deseret Depot headquarters in Utah to ship the shells by fast freight. That installation thereupon arranged for attaching a freight car containing the shells to a passenger train heading toward Huntsville. About the time this train was leaving Deseret a freight train loaded with the same type shell was leaving Parsons, Kans., where the Ordnance Department filled chemical shells with HE, for Deseret. At an intermediate point, the west bound train was sidetracked to allow the east bound train to pass. From then until the end of the war the Supply Division waged an intensive campaign not only to eliminate cross hauls but also to encourage more frequent shipments of cargo direct from manufacturer to user.[8]

Advent of the Supply Control Program

Efforts to improve procurement and distribution procedures were not confined to the CWS, but were characteristic of other elements of the Army

[8] (1) *Ibid.* (2) Rpt of CWS, 1945, pp. 77–78.

as well. In the ASF these efforts were closely related to a program to conserve manpower and matériel that got under way in late 1942 and continued throughout the war period. By the end of 1943 procurement of initial equipment for the Army had been carried out and many categories of munitions were in good supply. The year 1944 was to see a concerted attempt by the ASF to balance procurement and distribution.[9]

In the early summer of 1943 the newly created government "super agency," the Office of War Mobilization, requested each of the agencies engaged in government procurement to set up a board of review to study and make recommendations on improving methods of establishing requirements and of procurement practices generally. In response to this request, the War Department appointed a board, headed by Maj. Gen. Frank S. McCoy, USA, Ret. On 31 August 1943 the McCoy board submitted its report, including recommendations for more adequate screening of requirements and increased attention to inventory control. Several days later the War Department appointed another board, headed by Brig. Gen. George J. Richards, to resurvey the following five specific areas of requirements determination: (1) the strategic reserve; (2) theater reserves; (3) stockpiles in the United States; (4) day of supply; and (5) maintenance, distribution, and shipping loss factors. The Richards board came up with fifty-seven specific recommendations which were incorporated into a general implementing directive issued by the Deputy Chief of Staff, Lt. Gen. Joseph T. McNarney, on 1 January 1944.[10]

After issuance of this document generally referred to as the McNarney directive, the ASF set up a system aimed at closer co-ordination of the various phases of procurement and distribution. Known as the Supply Control System, it was formally announced in ASF Circular 67, 7 March 1944. Its aims were summarized as follows by the Requirements and Stock Control Division, ASF, at the time the system was being put into operation:

> The Supply Control System adjusts production to demands by requiring realistic estimates of equipment and weapons needed for:
>
> Supplying troops newly activated.
>
> Replacing losses due to wear and combat.
>
> Providing special equipment for unusual operations.
>
> Maintaining a proper level of supply in each overseas theater so that abnormal usage for short periods and interruptions in shipping will not endanger operations. These levels will average about 100 days of expected usage depending on theater location.

[9] (1) Richard M. Leighton and Robert W. Coakley, *Global Logistics and Strategy*, UNITED STATES ARMY IN WORLD WAR II (Washington, 1955), p 632. (2) Millett, *The Organization and Role of the Army Service Forces*, pp. 373–84.

[10] Smith, *The Army and Economic Mobilization*, ch. VII.

Maintaining a proper level of supply in U.S. depots so that fluctuating demands and production difficulties will not result in short supply. The maximum level of 90 days is decreased if production and issue experience justify less.

Building up a Strategic Reserve for emergency use. Estimates are checked against all pertinent factors including issue experience. From these needs stocks available in depots and returns of matériel from deactivated units, inactive theaters, and other sources are deducted. Production is then scheduled to meet but not exceed the balance of needs by months and quarters for a two year period.

The system further permits immediate quantitative identification of any stocks available for redistribution or disposal as surplus.[11]

The Supply Control System provided for two general categories of items, principal items and secondary items. For principal items a form was devised which summarized on a single page all important supply and demand information on a monthly basis for the three months preceding and the three months following the date of estimate, and for two quarterly periods and two semiannual periods thereafter. For secondary items a short form was devised. General instructions on the Supply Control System were published in an ASF Manual which went through several revisions.[12] In Headquarters, ASF, the Requirements Division was merged with the Stock Control Division, with the new organization to supervise the administration of the control system throughout the technical services.

In conformity with the provisions of ASF Circular 67, the Chief, CWS, established a Materiel Planning Branch in April 1944 to compute requirements under the Supply Control System. There was a difference of opinion between the two Assistant Chiefs, CWS, over who should control the work of this branch. General Waitt, Assistant Chief for Field Operations, believed he should have the responsibility because he felt that the determination of requirements should be entirely divorced from procurement and supply activities.[13] General Ditto, Assistant Chief for Materiel, maintained on the other hand, that the requirements function could not be separated from procurement and supply activities and that he should therefore have jurisdiction over the new branch.[14] General Porter intervened with a compromise solution by directing that the Chief of the Materiel

[11] Memo, Reqmts and Stock Control Div, ASF, sub: The Supply Control System. Reqmts and Stock Control Div ASF File.

[12] ASF Manual M-413, editions of 20 Jul 44, 22 Dec 44, and 10 Apr 45.

[13] (1) Memo, Brig Gen A. H. Waitt for Maj Gen Porter, 24 Feb 44, sub: Record Keeping and Use of Figures in Control of Operations—Responsibilities of Field Operations Command. (2) Memo, Brig Gen A. H. Waitt for Maj Gen Porter, sub: Army Supply Program. This memo was written to supplement the 24 Feb 44 memo. Both in CWS 314.7 Requirements File.

[14] Interv, Hist Off with Lt Col Lyman C. Duncan, 23 Jun 55. Duncan was chief of the Materiel Planning Branch (later Division) during World War II.

Planning Branch, Lt. Col. Lyman C. Duncan, report to the Assistant Chief for Materiel, but that the Assistant Chief for Field Operations should supervise those activities of the branch for which he had final responsibility.[15] General Porter apparently saw the need in this instance for a further application of the type of co-operative effort that had begun to develop in the Situation Room meetings. This is indicated by his action in appointing a Requirements Planning Committee, made up of representatives from the offices of the two assistant chiefs, to consider the supply and demand status of all CWS items.[16]

Shortly after the Supply Control System was inaugurated, the War Department revised its troop basis to include about 13,000 organizations. The Materiel Planning Branch computed requirements for these units on a Table of Allowances basis.[17] It used a key punch multiplier to obtain the gross requirement of chemical warfare items by multiplying the number of units, organizations, and individuals on the current troop basis by the stated number of items listed for the unit, organization, or individual on the Tables of Allowances.

The gross requirement was the keystone on which estimates were based under the Supply Control System. It was modified for each item in accordance with one or more of the following factors: stock on hand, estimated special requirements, current issue experience, amount in the pipeline needed to maintain an even flow of supplies, production lead time, impending standardization of a substitute item, abnormal replacement rates of principal components, and required special handling or storage.

At no time during the war did the determination of requirements develop into an exact science. There was the ever present risk of sudden and unforeseen demands upon the supply system and only the rash and unorthodox supply officer would postulate that there would be no military reversals, no sudden changes in tactics or strategy, no initiation of gas warfare. Gentlemen of what might be called the "old school" of supply planners tended to favor the maximum production and issue of every item needed. War, they felt, was by its very nature wasteful and the fortunes of war should not be jeopardized by possible shortages of any kind. The "Supply Control" school of planners, on the other hand, stressed the

[15] OC CWS Off O 7, 5 Apr 44.

[16] *Ibid.*

[17] Tables of Allowances were standardized extracts and condensations of individual tables of organization and equipment. Each table of equipment was a compilation of all the standard items of issue listed per unit or organization, or in some cases per person, within a particular arm or area.

need for considering the limits of the nation's natural resources and manpower, the relative importance of required munitions, and the intelligent use of all available logistics information. Until the very end of the war these two schools were represented in the CWS Requirements Planning Committee, although the views of the "Supply Control" group, backed as they were by the ASF, became ever more dominant.

The emphasis which the ASF placed on balancing procurement and distribution under the Supply Control System led the CWS to keep a more careful check on inventories. From April to June 1944 inspection teams composed of representatives of the Inspection, Technical, and Field Requirements Divisions, OC CWS, visited the various CWS depots and CW sections of Army depots to determine by actual count what material was available in the zone of interior for shipment overseas. With the assistance of depot personnel,[18] these teams inspected all items in the depots, and classified them as active, inactive, obsolete, surplus, or unserviceable. They found that 40 percent of the items were in categories other than active. On the basis of the teams' findings the chief's office compiled a 10-volume report listing the items throughout all the depots.[19] With this report as a guide, the CWS undertook a general house cleaning in its depots and sections to discard or declare surplus all useless items. Perhaps no single development during the war did so much to improve the quality of items stored and issued by the CWS.

Procurement and Distribution of Spare Parts

During the first year of war the CWS concentrated on the procurement of end items and paid little attention to the procurement of spare parts. The procedure for procuring parts was simply to divert a portion of components to the Indianapolis Depot or in certain instances to the Edgewood Depot or to one of the chemical sections of the War Department depots.[20] The quantity of matériel being set aside as spare parts proved entirely inadequate so that by the spring of 1943 the Office of the Chief,

[18] Memo, C Insp Div, OC CWS, for C Sup Div, OC CWS, 18 May 44, sub: Reinspection of Materiel in CWS and ASF Depots. CWS 314.7 Inspection File.

[19] Reinspection of all CW Materiel in Depots Within Continental United States Compiled by Inspection Division, OC CWS, 31 May 44. CWS 314.7 Inspection File.

[20] In February 1942 the Chief, Supply Division, OC CWS, decided to have CW spare parts stored at the Indianapolis Depot. Interv, Hist Off with Col Oscar Gullans, 6 Dec 54. Gullans commanded this depot in World War II. ASF did not officially designate the place as a spare parts depot until 14 May 43, under ASF Memo S-50-3-43.

CWS, was issuing parts to ports of embarkation "on a hand-to-mouth basis." [21] Reports on spare part shortages from the theaters of operation were becoming alarming. In November 1943 CWS organizations in Italy actually set up manufacturing lines to produce spare parts and a year later CWS organizations in France did the same thing.[22]

By early 1943 the ASF had become seriously concerned over the spare parts situation throughout all the technical services and was conducting a number of studies aimed at a solution.[23] It found that among the shortcomings in the CWS spare parts program, besides the delay in procurement, were lack of a complete system of stock numbering and identification, confused nomenclature, and absence of a definite procedure for checking estimates of actual usage in the field. The Chief, Control Division, OC CWS, in commenting on the findings of the ASF, admitted that unfortunately many of the criticisms were true, but added that efforts were being made to improve the situation.[24]

The first important step to improve the spare parts situation in the CWS was the activation of a Spare Parts and Catalog Branch in the Field Requirements Division in July 1943.[25] This branch, headed by Maj. John L. Eddy and located at Edgewood, prepared standard nomenclature and price lists, compiled requirements of spare parts, and prepared the spare parts catalogs for issuance to the field.[26] The catalogs contained photographs and sketches to permit easy identification in field use.

A further step toward the solution of the spare parts problem was taken as the result of an ASF policy announced on 6 July 1943. This policy provided that spare parts were to be issued to provide maintenance for not less than 12 months or more than 18 months and that such parts were to be delivered "simultaneously with equipment deliveries." [27] To carry out this directive the CWS made provisions in its Procurement Plan for 1944 to step up the production and distribution of spare parts. Under the

[21] Spare Parts for CWS Equipment (Report). ASF, G-4 Chemical Warfare Rpt 102, Apr 43. CG, ASF File.

[22] See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[23] Hist of Contl Div ASF 1942-1945, Appendix, Project 62. In OCMH.

[24] Ltr, C Contl Div, OC CWS, to Dir Opns Hq ASF, 11 Jun 43, sub: Spare Parts for Chemical Warfare Equipment. CWS 400, Army Supply Program, Apr-Jun 43.

[25] OC CWS Adm O 13, 3 Jul 43.

[26] Spare Parts for CWS Equipment. ASF, G-4 Spare Parts for CWS Equipment Rpt 144, Nov 43. CG, ASF File. This survey was conducted by Office of the Director of Stock Control, Maintenance Division, and Control Division, ASF.

[27] (1) ASF, Memo W 700-32-43, 6 Jul 43, referred to and quoted in *ibid.* (2) See also Hist of Contl Div ASF 1942-1945, Appendix, Project 62.

plan, the Industrial Division, OC CWS, was to furnish the installations promptly with lists of the spare parts to be procured by the contractors. In some instances the parts were to accompany the end item to the point of destination, in others they were to be shipped to the Indianapolis Depot.[28]

Another move to improve the spare parts situation came with the inauguration of the Supply Control System. In order to analyze the stock control position of each of the 10,000 CW parts, it was necessary to scrutinize carefully their procurement and supply status.[29] To obtain the necessary data on spare parts as well as on end items, the Materiel Planning Branch was assigned the mission of collating the Stock Status reports and the monthly procurement reports.[30]

In spite of the various measures taken to improve the situation the procurement and distribution of spare parts was still unsatisfactory in the fall of 1944. For one thing the provisions of the CWS Procurement Plan for 1944 were not working out as successfully as had been anticipated. The list of spare parts which the Industrial Division, OC CWS, was furnishing the procurement districts contained items which had lead times varying from twenty days to six months and which had to be procured from various contractors. The task facing the districts of procuring, storing, and shipping the parts was complicated by the Industrial Division requirement for simultaneous shipping of all parts on any procurement list. The Industrial Division eventually eliminated this particular problem by drawing up shorter lists, each containing parts having approximately the same lead time.[31]

In the fall of 1944 the Office of the Chief, CWS, reached the conclusion that the spare parts problem would not be fully solved until all the various functions—requisition, initiation of procurement, and distribution—were centralized at the Indianapolis Depot.[32] In late 1944 and early 1945

[28] Chemical Warfare Service Procurement Plan for 1944 Procurement, 12 Aug 43. CWS 314.7 Procurement File.

[29] The dollar value of spare parts procurement in CWS between July 1940 and October 1945 amounted to over $78,000,000. See Memo, AC Supply and Dist Div to C Contl Div, OC CWS, 1 Feb 46, sub: Dollar Value of Spare Parts. CWS 314.7 Spare Parts File.

[30] Résumé of Activities, OC CWS, for Week Ending 7 Oct 44. CWS 314.7 Supply Control File. (2) Memo, Dir Plans and Opns ASF for C CWS, 31 Oct 44, sub: Report of Status of Spare Parts Supply Control and 1st Ind thereto. CWS 400 Oct thru Dec 1944. (3) OC CWS Off O 5, 24 Feb 45.

[31] (1) Ltr, ExO Ind Div, OC CWS, to CO NYCWPD, 28 Aug 44, sub: Spare Parts Study. CWS 400. (2) Ltr, Actg C Ind Div, OC CWS to NYCWPD, 10 Nov 44, Sub: Spare Parts Procurement, and 1st Ind. CWS 400.

[32] Memo, C Contl Div, OC CWS, for AC CWS for Field Operations, 19 Oct 44, sub: Spare Parts. CWS 314.7 Spare Parts File. This memo was written by S. J. Levitan of the Control Division.

this centralization was carried out. All requisitions for spare parts were sent directly to the Indianapolis Depot instead of, as formerly, to the various CWS depots and sections. This innovation resulted in a saving in delivery time of from 10 to 30 days on parts produced by the CWS and of from 15 to 40 days on parts bought under contract. Indianapolis Depot established direct contact with the procurement district offices on packaging and shipping problems and in many instances dealt directly with the manufacturers of the parts in the districts.[33]

Improved Maintenance Practices

Greater emphasis on maintenance of matériel was a feature of the campaign to bring procurement and distribution into balance.[34] In the period between the wars the quantity of chemical warfare supplies was extremely limited and consequently maintenance was not much of a problem. Most CW supplies were stored at the Edgewood Depot, which had access to the shops at the arsenal to do required maintenance. In the field the CW sections in division and company headquarters were responsible for first and second echelon maintenance while repair shops near the posts or at Ordnance Department depots carried on the higher echelon repairs.[35] The CW sections normally consisted of one officer and several enlisted men.

In the first two years of the war more than 75 percent of all maintenance activities were third, fourth, and fifth echelon.[36] Third and fourth echelon work was accomplished at the principal shop located at Edgewood Arsenal or at the other shops at Camp Sibert and Huntsville, Pine Bluff, and Rocky Mountain Arsenals. Fifth echelon maintenance or complete rebuild was generally done by contracting with the manufacturer of the item. In the case of the gas mask, the CWS awarded contracts to four industrial concerns who were not the original manufacturers.[37] Because facilities were limited at the Chemical Warfare shops, it was also occasionally necessary to send equipment to commercial machine shops to expedite third

[33] Rpt of CWS, 1945, pp. 61–64.

[34] Maintenance was defined as "care taken and work done to keep any item of equipment in good working condition" in TM 20–205, Dictionary of U.S. Army Terms, 18 Jan 44.

[35] First echelon maintenance was performed by the individual, while second echelon maintenance was carried out by an organization using tools provided in the T/O&E.

[36] Third echelon maintenance was performed by depot companies, and fourth echelon maintenance was accomplished in rear areas. Ltr, C Fld Serv, OC CWS, to CG AGF, *et al.*, 15 Aug 42, sub: Maintenance of CWS Materiel. CWS 470.72. As a result of an ASF directive of May 1943 two echelons were made out of the third, and the fourth echelon then became the fifth echelon.

[37] These contractors were: Hub Hosiery Mills of Boston; Cluett Peabody, Inc., of Troy, N.Y.; Dryden Rubber Co. of Keokuk, Iowa; and Joyce, Inc., of Los Angeles.

and fourth echelon rehabilitation.[38] From 1942 until the close of the war twenty chemical maintenance companies were trained for the ground and service forces and fourteen companies were activated for the assistance of the Air Forces. These companies helped with the maintenance task in the United States, but by the late spring of 1944 all but one of the maintenance companies then in existence were serving at overseas stations.[39]

Thus, with an increasing maintenance workload caused by increasing stocks, the CWS was now beginning to meet serious maintenance problems. The existing shops were proving inadequate and the practice of contracting fifth echelon maintenance to the original manufacturer was proving to have drawbacks. One drawback was that certain items of equipment, such as the power driven decontaminating apparatus, came in several models and each manufacturer usually could repair his own model only. Another drawback to contracting was that a number of manufacturers estimated the cost of repair on the basis of a complete rebuild job which made CWS maintenance costs unduly high. Securing officers with the necessary technical knowledge to supervise maintenance operations was another difficulty.

These problems had arisen earlier in other technical services, and the Maintenance Division, ASF, had initiated two far-reaching programs in the search for solutions. One of these was the reclamation program which was defined as "the process of restoring to usefulness condemned, discarded, abandoned, or damaged property or components thereof by repair, refabrication, or renovation." [40] By the summer of 1943 this program was being emphasized in the CWS, with good results. For example, a number of WP shells had failed in proof firing and it had been found that there was an excessive quantity of water in each shell. To overcome this condition the workers tapped the shells at the nose by drilling a small hole and draining off the excess water. They then drove a tapered pin into the shell to form a closure. After these reworked shells were reproofed, they functioned in a satisfactory manner. Again, some arsenals had a practice of burying their worn out reactor coils. But Huntsville Arsenal developed a method of reclaiming these coils by dipping them (after they had been given some decontamination treatment) in refuse oil and then burning them in a hot fire for several hours. The arsenal sold the burnt iron as

[38] Ltr, C CWS to CG ASF, Attn: Dir Maint Div, 29 Apr 43, sub: Improvements of Maintenance Practices and Procedures. CWS 400.4.

[39] See Brophy and Fisher, *Organizing for War,* app. F.

[40] ASF Cir 140, 6 Dec 43.

scrap. The CWS extended this practice to its other arsenals.[41] Another ASF program aimed at improving maintenance practices was the establishment of centralized maintenance shops. These shops, first activated in the fall of 1943, were under service command jurisdiction and repaired equipment of all the technical services.[42] The centralized shops were organized along functional lines and included the following individual shops: automotive, armament and instrument, clothing and equipment, electrical equipment, machine, and paint.[43]

The CWS, like other technical services, was entitled to the use of the ASF combined shops, but at first hesitated to use them because the personnel was not familiar with chemical warfare equipment.[44] Officials felt that trained CWS field representatives should be dispatched to the service commands to offer assistance on CW items. Beginning in the spring of 1944 a number of officers, selected on the basis of initiative and sound judgment, were sent out on this mission. Before departing, they were instructed to contact the directors of maintenance in the service commands to assist them in selecting the shops best equipped to handle chemical warfare items. They were directed to "inspect all large equipment such as the power driven decontaminating apparatus; smoke generators; compressors; equipment (water heater) for the power driven decontaminating apparatus; trailers; Chemical service trucks; cranes with swinging boom . . . ." They were to render assistance to commanding officers of CW depots on technical matters relating to the repair, maintenance, and storage of CW items.[45]

The problem of fifth echelon maintenance was solved by setting up a fifth echelon maintenance shop at Rocky Mountain Arsenal. This shop was established in November 1944, but it was several months before it got into operation. In the spring of 1945, as redeployment planning for Pacific operations got under way, it appeared that the capacity of the Rocky Mountain shop would be inadequate for repairing matériel needed

[41] Memo, C Contl Div, OC CWS, for CG ASF, Attn: Dir Maint Div, 21 Jul 43, sub: Distribution of Reclamation Information. CWS 400, July 1943.

[42] WD Memo 210-25-43, 7 Sep 43.

[43] Memo, Dir of Opns ASF for QMG, 31 Jul 43, sub: Combined Shops at Posts, Camps, and Stations. CWS 314.7 Maintenance File.

[44] WD Cir 7, 5 Jan 44, outlined the general procedure for using the shops. This circular was later amended by WD Cir 90, 29 Feb 44.

[45] Instructions to Maintenance Branch Inspectors, 9 Jun 44. These typed instructions are reproduced as Appendix N in Bernard Baum, Leo P. Brophy, Sylvester J. Hemleben, Chemical Warfare Supply Program, pt. 4, Storage and Maintenance, vol. IV, in the series History of the Chemical Warfare Service in World War II (1 July 1940–15 August 1945).

in the Pacific and another fifth echelon shop was opened at Huntsville Arsenal.[46]

The return of overseas matériel necessitated the formulation of a plan for receiving, classifying, and repairing various CW items. In conformity with a directive from the Distribution Division, ASF, the Chief, Supply Division, OC CWS, drew up such a plan in the spring of 1945. This plan divided CW matériel into six categories and established receiving ports and classification facilities for each category. To illustrate, flame throwers, classified as Class B items under the plan, were to be received at the east and west coast ports and at New Orleans, and were to be sent to Rocky Mountain Arsenal for repair.[47]

The problem of securing officers to supervise maintenance work was met by initiating a two-week training course at Camp Sibert. This course was first given from 28 May to 10 June 1944 and was repeated on two occasions in the summer and fall of 1944. An officer with extensive experience in training maintenance companies was selected as instructor. The course covered both theory and practice in maintenance of specific chemical warfare items, such as pumps for decontaminating apparatus made by different manufacturers, M1A1 and M2-2 flame throwers, and the truck, crane, swinging boom, M1.[48]

In addition to the problems of spare parts and maintenance which the CWS faced in its efforts to balance procurement and distribution, there were problems of property disposal and contract termination.[49] No sooner had the CWS procured its initial equipment than problems of property disposal began to arise. By early 1944 delay in disposing of inventory and industrial property was leading to delay in contract terminations throughout all the technical services.[50]

[46] Memo, C Ind Div, OC CWS, for CO HA, 15 Jun 45, sub: Fifth Echelon Maintenance Shop. CWS 319.1.

[47] Ltr, C Sup Div, OC CWS, to CG ASF, Attn: Distribution Div, 15 May 45, sub: Return of CWS Materiel from Overseas. CWS 400 May–Jun 1945.

[48] Baum, Brophy, and Hemleben, Chemical Warfare Service Supply Program, Storage and Maintenance, p. 778 and app. L.

[49] Property disposal and contract termination were also closely related to demobilization planning and will be discussed in that connection. See ch. XVII below.

[50] (1) Minutes of Meeting Staff Conference ASF, 22 Feb 44, p. 3. ASF Hist Files, National Archives. (2) Under Secretary of War Patterson later remarked: "Prompt and equitable settlement of terminated contracts aids production by removing impediments to the maximum utilization of production facilities, thereby enabling contractors to meet new demands for war production promptly and otherwise expedite the carrying on of war work." See Memo, USW for CG AAF and CG ASF, 12 Jan 45, sub: Relation of Production to Readjustment Activities. CWS 400.12.

By the end of 1943, when the Army had completed its initial distribution of matériel, the CWS had finished the bulk of its new construction and had gained valuable experience in procurement, inspection, and distribution operations. The second half of the war witnessed greater stress on improvement of the supply system through adoption of more refined administrative procedures and through programs aimed at better maintenance practices and better control of spare parts. Problems of maintenance, spare parts, contract termination, and property disposal constituted potential bottlenecks to production.

CHAPTER XIV

Procurement of Defensive Matériel

In addition to large quantities of service equipment, toxic agents, and raw chemicals the CWS in World War II procured a variety of defensive and offensive munitions. Included among the defensive items were the gas masks, impregnite, impregnating plants, protective ointment, detector kits, decontaminating apparatus and such miscellaneous items as shoe impregnite and dust respirators.

Gas Mask Procurement

During the years between the wars the Army manufactured gas masks for troops in its own production facility at Edgewood Arsenal. It was on this production line that the Chemical Warfare Service developed the basic tools and techniques for mass production of the service mask. But CWS planners were aware that in time of war a fully mobilized citizen army could not possibly be equipped with gas masks from a single small production line. From the early 1930's onward they assumed it would be necessary to bring private industrial firms into the gas mask program on a large scale as soon as mobilization became likely. Between 1934 and 1941 the War Plans Division at Edgewood Arsenal completed arrangements for private production facilities capable of turning out 900,000 masks a month. As already noted, the first assembly plant established in an industrial facility was set up by means of an educational order.[1] Completed just as the armed forces were beginning to expand to war strength, the educational orders for gas masks were promptly replaced by full-scale produc-

[1] See ch. XII above.

tion contracts which were to yield more than thirty million industry-produced gas masks before the end of World War II. By the end of 1940, mass production of gas masks was well under way.

Mass production of the gas mask gave rise to a number of problems.[2] The mask and its major components were specialized military items unfamiliar to private industry; moreover, as equipment which might mean the difference between life and death to the individual soldier, the Army required a high standard of precision in its manufacture. The first need of the contractors was for skilled and experienced workmen. There was but one place, Edgewood Arsenal, from which to draw them; accordingly men and women from Edgewood's gas mask plant joined the assembly lines at the factories as instructors and inspectors. In some cases they remained to form the nucleus of permanent inspection teams.

Without the assistance of the experienced employees from the gas mask plant at Edgewood Arsenal, the contractors would not have been able to operate, for as just indicated, nowhere in industry were there workers with the necessary skills. After picked employees of the contractor had learned to perform their tasks, they in turn became instructors to other selected employees.

The training of skilled and semiskilled workers was only one of the perplexing matters that the gas mask contractors faced. Like many other wartime procurement difficulties, this problem was not confined to a particular item or a particular contractor. Another problem was the impact on manufacturing operations resulting from changes in production schedules. The fact that such changes were inherent in the system of wartime supply did not lessen the impact. A change in a gas mask schedule made it necessary for the contractor to cut back the number of workers on the assembly line. These workers were often employed elsewhere in the plant, and under company policies they were usually not obliged to return to their former jobs. If a demand arose for increased production of gas masks, the contractors had to train new workers. The situation became particularly complicated when a contractor had several contracts on the mask running simultaneously.

Both the CWS and the contractors assembling gas masks had trouble procuring components. Under the educational order program the CWS had

[2] Discussion of these problems is based on: (1) Histories of the CWS procurement districts in World War II; (2) History of the Johnson and Johnson Gas Mask Factory; (3) Interv, Hist Off on 12 Nov 57 with the following World War II gas mask supervisory employees of the Goodyear Tire and Rubber Co., Akron, Ohio: H. E. Morse, C. S. Davis, Wayne White, and E. Wendt.

procured components from relatively few contractors, but once full-scale production got under way the service had to add many additional sources for such noncommercial items as faceblanks, valve parts, canister parts, treated charcoal (whetlerite), and eyerings. In many instances the components furnished did not prove satisfactory and the CWS had to station inspectors at the plants of all major manufacturers of components.

Another difficulty in the manufacture of the gas mask resulted from slight variations in the faceblank molds of the different mold manufacturers. Because each mold maker used a slightly different pattern the faceblanks also had slightly different patterns and could therefore not be successfully assembled with the same tools. Many faulty assemblies took place with resultant delays in production.[3]

The mask which industry began to produce in 1940 was the standard Army service mask, M1A2-9A1-4, together with its economically priced counterpart, the training mask, M2A1-1-1. In some respects these items proved difficult to adapt to assembly line techniques. The M1A2 facepiece not only needed careful handwork at such points as its eyering assembly, but it also had a potentially vulnerable chin seam, which had to undergo an elaborate process of repeated cementing, taping, and baking to meet specifications. One contractor, Firestone Rubber and Latex Products Co. of Fall River, developed an automatic chin seam vulcanizer to speed the work.[4] The ultimate solution to the problem however, was to replace the M1A2 faceblank altogether by getting the simpler, seamless, all-rubber molded faceblank into production. It took some time and care to produce the molds in the needed quantities and within the close tolerances required. The first attempts to produce molded faceblanks in quantity for the service masks were undertaken late in 1940. A number of changes in the rubber composition and molding techniques had to be worked out before the process could be depended upon to turn out the intricately shaped forms without having a large percentage unacceptable because of cracks or other

[3] In 1948 the Chemical Corps awarded a contract to Firestone Industrial Products Co., Akron, Ohio, to make a study aimed at improving the industrial mobilization plan for the gas mask. In compiling data, the Firestone Co. interviewed representatives of the various World War II gas mask contractors. Among other things the Firestone report recommended that in the future all mold manufacurers should use identical patterns. See Industrial Mobilization Planning Study, Mask, Service, Combat, M-5-11-7, Chemical Corps Contract W 18-035-CM-834 Phase I, 5 March 1948, p. 65. ETF 611.69-2/2. Hereafter referred to as Planning Study, Mask.

[4] (1) History of the Pittsburgh CWPD, Revised 31 July 1945, p. 145. Referred to hereafter as History of Pittsburgh CWPD. (2) History of the Boston CWPD in World War II, vol. 9, p. 80. Referred to hereafter as History of the Boston CWPD.

flaws.[5] By June 1941 the fully molded faceblank was ready to replace the M1A2 on the assembly lines.

The transition to mass production by industry brought new ideas as well as new problems to the gas mask assembly line. These ideas were introduced after some of the methods and devices which through the years had met the needs of the small pilot plant at Edgewood Arsenal were found inadequate for the demands now made upon them. For example, the firms that were turning out training masks (an item which differed from the standard service masks principally in its use of a simple cylindrical canister) soon became dissatisfied with the machine Edgewood Arsenal had designed to fill the canisters. They felt that it did not meet the standards of current commercial technology, and lost little time in arbitrarily replacing it with a more up-to-date filler borrowed from the food canning industry.[6]

By December 1941 the mass production of service and training masks by industry had been under way for a year. Despite the many problems of inexperience and adjustment, well over two million masks had been delivered to the Army, and production capacity had already exceeded ten thousand masks per day.[7] The nation's entry into active warfare only accelerated the existing program. There was, however, one major change of emphasis. The training mask, whose principal virtue lay in the fact that it was cheaper than its regular service counterpart, had never been intended for use in combat. Training mask production lines were therefore gradually shifted to service mask assembly, and by mid-1942 the training mask had been virtually dropped as a production item.[8]

But if one gas mask program was marked for conclusion after war came, another was suddenly and vigorously resuscitated. The period of educational orders had witnessed a small-scale trial production program for noncombatant gas masks. In 1940 the Chemical Warfare Service selected five firms, none of them experienced in such items, and contracted to set up complete noncombatant mask production lines in each for turning out a single educational order of gas masks. On the basis of this experience

[5] History of the Pittsburgh CWPD, pp. 144–45.

[6] (1) *Ibid.*, pp. 159–60. (2) History of the Boston CWPD, vol. 9, p. 39. (3) Interv, Hist Off with Col Victor C. Searle, Cml C, 4 Oct 56.

[7] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 21.

[8] (1) History of the Boston CWPD, vol. 9, p. 38. (2) History of the Pittsburgh CWPD, p. 149. (3) Memo, C Ind Svc CWS for USW, 13 May 42, sub: Rpt of Accomplishments of CWS. CWS 400.12/106–139.

the CWS after Pearl Harbor began mass production of civilian masks. For once, the service had no difficulty attracting potential producers. Several hundred applicants, hearing of a defense item which would be made by a comparatively small plant, solicited contracts. The CWS planners reckoned that for optimum production efficiency an individual plant should be capable of turning out 125,000 masks per month. This led to the conclusion that about twenty good sized producers would be preferable to a large number of small fabricators, and production contracts were ultimately assigned on this basis. Three of the original five educational order contractors were considered capable of undertaking full-scale production and over a dozen additional contractors were obtained to fill out the program. The selection was such that each of the six CWS procurement districts had two or more suppliers within its jurisdiction.[9]

By midsummer of 1942 the full-scale production program for noncombatant masks was under way. From the outset there were difficulties. The CWS, as a result of experience gained in educational order production, was convinced that the fabric facepieces needed a coating of natural rubber in preference to synthetic plastics if they were to have a firm, leakproof fit.[10] This requirement at once ran up against the sudden crisis in the nation's rubber supply, and though a limited amount of rubber was at last made available for the program, the CWS and its customer, the Office of Civilian Defense, had to accept a production ceiling of 8,500,000 masks. On the production line itself, shortages of materials and components hampered scheduling. The outlet valve case proved a particularly troublesome bottleneck until the molds needed to make it could be hurried to completion.[11] Despite difficulties the program reached its assigned goal approximately on schedule. In 1943 production of noncombatant gas masks came to a halt, and thereafter about half the production lines were maintained on a standby basis.

During 1942 the program for service gas masks was vigorously carried forward to meet the demands of the rapidly increasing Army. Since the service mask formed part of every soldier's equipment, the rate at which

[9] (1) Summary of Conference, OC CWS, 13 Mar 42, re Noncombatant Gas Mask Assembly Plants. (2) Maj R. D. Ball, Gas Masks, p. 39. Both in CWS 314.7 Gas Masks File.

[10] (1) History of the Boston CWPD, vol. 9, p. 23. (2) Interv, Hist Off with G. H. Titcomb, 7 Nov 56. Titcomb served as both civilian and officer in several protective equipment assignments, including Chief, Protective Equipment Section, Industrial Division, OC CWS.

[11] (1) History of the Boston CWPD, vol. 9, p. 28. (2) History of the Dallas CWPD, February 1942–June 1944, pp. 73, 75–77. (3) Memo, C Ind Service CWS for USW, 6 May 42, sub: Rpt of Accomplishments of CWS. CWS 400.12/106–139.

the mobilization of military manpower was proceeding required full use of all available production facilities. To those already at work on the service mask the CWS added a new end item assembler by converting Sprague Specialities Co. of North Adams, Mass., from a training mask line to the more urgently needed service mask. In 1943 the west coast was brought into the program when the San Francisco district set up service mask production at the plant of the Simmons Co. That same year the Dallas district began contracting with B. F. Goodrich Co. for production of the service mask in Clarksville, Tenn. By November 1943 service mask production had reached its peak rate, nearly a million a month, as compared with a prewar monthly rate averaging about two hundred thousand.[12]

The service mask that was being turned out at the end of 1943 was the new lightweight model, the M3-10-6, which had been developed in 1942. The first essay at putting the new mask into production was entrusted to the Pittsburgh district's end-item contractor, the Goodyear Tire and Rubber Co. of Akron, Ohio, which set up a pilot line for it in January 1943, without interrupting its regular production. The contract called for an initial production of 150,000 lightweight masks, but barely a tenth of that number had been assembled when the program was temporarily halted. So many practical difficulties had arisen in meeting the original specifications that these had to be altered somewhat before production could continue. Among the trouble spots singled out for special notice were the canister assembly and filling operations, the crimping of eyerings in the M3 facepiece assembly, and the sewing of the M6 carrier. The carrier turned out to be the main bottleneck, and the district ultimately had to call a conference of the CWS officers stationed at the plants of the carrier contractors before a standard design meeting both CWS requirements and production needs could be worked out. But by the end of May 1943 product engineering had advanced to a point where the CWS was able to negotiate full-scale production contracts with Goodyear and its other prime contractors. By August the new mask, with its nosecup, 18-inch hosepiece, cylindrical canister, and carrier, had replaced the old on all existing production lines and was being turned out by the new facilities at San Francisco and Clarksville as well.[13]

[12] (1) History of the Boston CWPD, vol. 9, p. 65. (2) History of the San Francisco CWPD in World War II, pp. 71-72. (3) History of the Dallas CWPD, February 1942-June 1944, p. 74. (4) CWS Report of Production, 1 Jan 40 through 31 Dec 45.

[13] (1) History of the Pittsburgh CWPD, pp. 161-68. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45.

Though Goodyear's pilot plant experience had served to correct some major difficulties, problems still remained at the assembly line level. The principal distinctive feature of the new facepiece was its nosecup, almost a mask within a mask, which had to be carefully vulcanized into place, simpler methods of attachment having proved impractical.[14] This process was speeded up after Firestone Rubber and Latex Products Co., one of the end-item contractors in the Boston district, developed and put into use a machine that vulcanized the nosecups to the facepieces automatically. A large surplus stock of old style 27-inch hosepieces ceased to be a problem when the contractors successfully demonstrated that a satisfactory 18-inch hosepiece could be fashioned from two 9-inch remnants, thereby making every two old style hosepieces a potential source of three lightweight pieces.[15] The problem of handling the recently developed whetlerite on the canister line called for some new techniques and a good deal of care to prevent overexposure of the impregnated charcoal to the atmosphere.[16]

The Pittsburgh district bore most of the burden of keeping the gas mask program supplied with charcoal. Early production contracts were for nutshell and wood charcoals. The major source at this stage was the Barnebey-Cheney Engineering Co. of Columbus, Ohio, a pioneer in the field, which operated not only charcoal activating kilns but also a Zanesville, Ohio, plant where charcoal was converted to whetlerite. A CWS contractor-operated plant in Fostoria, Ohio, used a zinc chloride process to produce a wood charcoal which met standards at first, but which later proved comparatively expensive and unsuited to the manufacture of the ASC form of whetlerite in use by 1943. In that year the Pittsburgh Coke and Chemical Co. opened up a new domestic source, bituminous coal, for the mass production of whetlerite. After the company had demonstrated the practicability of making charcoal from bituminous coal, the government built two charcoal plants for the Pittsburgh company.[17] A little later, the CWS acquired the plant at Zanesville for the Pittsburgh Coke and Chemical Co. to operate. The elaborate test procedures required for the effective inspection of ASC whetlerite led the Pittsburgh district's chief

[14] History of the Pittsburgh CWPD, p. 168.

[15] (1) History of the Boston CWPD, vol. 9, pp. 66, 78. (2) History of the Chicago CWPD, 1 July 1940 through 31 December 1944, vol. 1, p. 57.

[16] History of the Pittsburgh CWPD, p. 165.

[17] Interv, Hist Off with R. C. Moore, 14 Nov 57. Mr. Moore was in charge of Pittsburgh Coke & Chemical Co.'s charcoal program in World War II.

inspection officer to urge that the CWS set up a central testing laboratory in the Pittsburgh area. The service adopted the suggestion, and by mid-February of 1944 a central laboratory was in operation at Carnegie, Pa., near the contractor's plant, and beginning the process of taking over the major responsibility for whetlerite inspection.[18]

The Rubber Crisis

The most difficult problem confronting the gas mask program was the critical wartime shortage of its principal ingredient, crude rubber, as noted earlier. In peace or war the United States had to have an annual rubber supply running to upward of half a million long tons just to keep its rubber tired vehicles operating. The source of nearly all the crude rubber used in America was the plantations of Southeast Asia. The onset of a Pacific war, followed within weeks by the loss of most of the rubber regions to the enemy, left the United States facing a major emergency in rubber supply by the spring of 1942. The government quickly imposed rigid limitations on the use of the country's existing rubber stockpiles, while a tremendous new production program for synthetic rubbers was rushed into being.

Despite the fact that the Chemical Warfare Service for the time being had a large enough share of the overall military allotment of rubber to continue its service mask programs as planned, the post-Pearl Harbor procurement of noncombatant gas masks was in trouble from the outset. The item, being specifically nonmilitary, had no proper claim on military allocations of strategic materials. Moreover, civilian authority as represented by the newly organized War Production Board (WPB) tended to discourage the issuance of rubber allotments for the mask. Concern over the immediate and dangerous rubber emergency outweighed concern over a hypothetical gas attack on continental United States. The expressed intention of CWS officers to aim for a total program of fifty million noncombatant masks, involving the probable expenditure of some ten thousand tons of rubber, met with opposition firm enough to force a compromise. The WPB agreed to supply 1,360 tons of reclaimed rubber, sufficient for five million noncombatant masks for domestic use plus an additional three and a half million destined for Australia. Officials of WPB hoped that the CWS would soon be able to standardize a noncombatant facepiece using

[18] History of the Pittsburgh CWPD, pp. 178–92.

some substitute plastic as a fabric coating. Though work on such a product was being carried on it had not yet produced a facepiece meeting the requirements.[19] When later in 1942 it developed that the original allocation would not be large enough to complete the masks on order, WPB reluctantly granted an additional allocation of 750 tons of reclaimed rubber, over the objections of its own Office of Civilian Supply.[20]

Notwithstanding that by 1943 the rapidly increasing output of synthetic rubbers was beginning to have its effect on the rubber emergency, the stock of natural rubber continued to dwindle. By the spring of that year it was becoming plain that mass production of the natural rubber service mask could not go on indefinitely. The CWS had already improvised measures to stretch its rubber allocation for the time being, first by reducing the percentage of latex in the prescribed compound and then by authorizing increased use of reclaimed rubber. But a change to an all-synthetic mask was fast becoming a necessity.

The Office of the Rubber Director, WPB, brought matters to a head early in June 1943 by setting up a committee, representing gas mask producers, the CWS, the Navy, and the WPB, to plan the change-over. The committee, under the chairmanship of J. J. Allen of the Firestone Rubber and Latex Products Co., met monthly beginning in June. Though the CWS was doing most of the necessary development work through its laboratory at the Massachusetts Institute of Technology, a great deal of technical information on mixing and handling compounds based on synthetics was exchanged through the committee by the industry representatives. It was the general conviction that butyl rubber was the synthetic that would be best for the purpose, and throughout the summer the planning and experimentation was based on this conclusion. Planners expected a butyl service mask to be in production by early fall. Then in September they realized that the expected output of butyl rubber could not be counted upon, and they quickly decided to proceed with the conversion plans using neoprene instead. In October the CWS placed educational orders for pilot lots of

[19] (1) Memo, W. Allen for C Rubber Branch, WPB, 6 Feb 42, sub: Gas Masks for Civilian Defense. (2) Memo, W. Helburn for C Rubber Branch WPB, 25 Mar 42. (3) Ltr, Brig Gen Paul X. English to C Rubber Branch WPB, 26 Mar 42, sub: Rubber for Non-Combatant Gas Masks. (4) Memo, C Rubber Branch WPB for Brig Gen English, 27 Mar 42, sub: Reclaimed Rubber for Non-Combatant Gas Masks. All in WPB 572.4. (5) Titcomb interv, 7 Nov 56.

[20] (1) Memo, E. J. Casey, 4 Nov 42, sub: Face Pieces for O.C.D. Gas Masks. WPB 577.0413. (2) Memo, Asst Deputy Rubber Director, WPB for C CWS, 3 Nov 42, sub: Reclaimed Rubber for Noncombatant Gas Masks. (3) Memo, C Rubber Sec Off of Civilian Supply for C Appeals Bd, 17 Nov 42, sub: Additional Allocation . . . for . . . Gas Masks. Both in WPB 571.14.

synthetic components (faceblanks, hose tubes, and nosecups) with its principal contractors, and on 1 November the Rubber Director's order limiting gas masks to 50 percent crude rubber in November and none subsequently became effective.[21]

For more than a year thereafter the Army's standard service masks—both the M3 lightweight mask standardized earlier and its shortlived successor, the M5 combat mask—were made of neoprene. As in the case of any major change in specifications, there was an occasional hitch on the production lines. Some of these hitches were caused by the fact that batches of neoprene compound were not always uniform.[22] A more critical problem arose when one contractor attempted to produce faceblanks for the complicated optical gas mask from neoprene. The neoprene stock refused to take molding acceptably, and nearly all the first batch of one thousand faceblanks failed to pass inspection. The contract had to be terminated.[23] But with these exceptions, production of neoprene masks proceeded smoothly enough.

Not until the neoprene masks had reached the troops in the European Theater of Operations and experienced cold weather—that is, not until the winter of 1944–45—were the shortcomings of neoprene fully appreciated. The "black rubber" masks, as they were called, were likely to stiffen into deformed shapes at low temperatures, making it impossible to obtain a gastight fit. The theater let it be known that it wanted no more of them. This tendency of neoprene to develop "cold set" was not unknown in 1943. According to a WPB historian the output of neoprene had been reduced in the spring of 1943 because its unreliability at low temperatures limited its usefulness.[24] The Gas Mask Industry Technical Committee, which had co-ordinated the work leading to the adoption of neoprene, had been aware of the difficulty. The committee, when considering formulas the contractors were preparing to use, had apparently left approval of the neoprene

[21] (1) Minutes of Third Meeting of Gas Mask Industry Technical Committee, 17 Aug 43. (2) Memo, S. P. Thacher, Rubber Branch ASF for C CWS, 25 Aug 43, sub: Development of Synthetic Rubber Gas Masks. (3) Ltr, J. J. Allen to Capt F. G. Reinke, Rubber Branch ASF, 18 Oct 43. All in ASF 470.72. (4) Memo, S. P. Thacher for Rubber Director WPB, 2 Oct 43, sub: Proposed Directive Eliminating Crude Rubber . . . in Gas Masks. (5) Memo, S. P. Thacher for Chiefs of Technical Services, 13 Oct 43, sub: Proposed Directive . . . Both in ASF 423.

[22] History of the Pittsburgh CWPD, p. 171.

[23] History of the Boston CWPD, vol. 9, pp. 176–77.

[24] Civilian Production Administration, Industrial Mobilization for War: History of the War Production Board and Predecessor Agencies, 1940–45, vol. II ch. V, p. 94. Unfinished typescript draft in WPB Policy Files.

compounds to the CWS Laboratory at Massachusetts Institute of Technology.[25]

The Latter War Years

At the time the shift to synthetics was made, the production rate for gas masks was just passing its wartime peak. With the completion of the Army expansion program, there was a leveling-off in gas mask requirements. By February 1944 the cutbacks in scheduled production were extensive enough to justify a substantial reduction in assembly facilities. Accordingly, Goodyear was dropped from the program that month, and Sprague Specialities of North Adams, Mass., ceased production when their current contract was completed in April.[26]

The cutback coincided with the start of production on a new service mask, the M5-11-7 combat (or assault) mask. The CWS meant to ultimately replace this new item, a hoseless mask with a cheek mounted axial-flow canister and a new waterproof carrier, but at the outset scheduled only limited production with a single assembler, Firestone of Fall River. The principal production difficulties were in the assembly of components. New seaming and filling machines had to be installed for the M11 canister, an item radically different from the radial-flow canisters that had preceded it. The filters took the form of elaborately pleated shells of specially treated absorbent paper. Although a comparatively simple shell pattern was available, the CWS had also developed a pattern involving concentric pleats and wanted comparative field reports on the two types. Consequently, both types were produced. The concentric filter was considerably more troublesome to assemble. The M7 carrier, a complex item made of butyl coated duck, was a source of trouble from the start. The specifications, especially those for the waterproof closure, were such as to make for an inherently awkward assembly job.[27]

The Dallas district brought its principal gas mask contractor, the B. F. Goodrich plant at Clarksville, Tenn., into the combat mask program in September 1944, but the program itself was nearing a sudden end. Though the problem raised by the assemblers of canisters and carriers were not unusual, the difficulties which the combat facepiece itself presented were

[25] Ltr, J. J. Allen to Capt F. G. Reinke, Rubber Branch ASF, 18 Oct 43. ASF 470.72.

[26] (1) History of the Pittsburgh CWPD, pp. 163-64. (2) History of the Boston CWPD, vol. 9, p. 68.

[27] (1) History of the Boston CWPD, vol. 9, pp. 121-36. (2) Interv, Hist Off with G. H. Titcomb and E. S. Graves, 7 Nov 56.

another matter. The attempts to convert faceblank molds to M5 production had not been successful, and the faceblanks themselves had so high a rejection rate that by the end of August the CWS was ready to admit that continued production of the M5 was not worth the trouble. The contracts were terminated accordingly, with the M3-10A1-6 resuming its status as the standard service mask.[28]

The M3 was not the only service mask in production at the end of 1944. A salvage and reconditioning program of steadily increasing proportions had brought into being the lightweight service mask M4-10A1-6, which was manufactured by adding the nosecup, hose tube, canister, and carrier of a lightweight mask to a reconditioned M2A2 rubber facepiece. The M4 had been developed and approved late in 1942 as a stopgap item to be turned out while the production difficulties of the new M3 were being remedied.[29] It was not produced in any substantial quantity, despite the original plan, until the beginning of 1944. From then on it ranked as an important factor in the nation's gas mask output, and several major contractors were kept busy dismantling used heavy service and training masks so that the M4 assembly lines could be kept supplied.

The reconditioning program assumed a new importance in January 1945, after the using arms had declared the neoprene facepiece unsatisfactory From then onward the CWS mask program depended on the output of natural rubber facepieces from the reconditioners. By the summer of 1945 an elaborate process was under way of recalling neoprene masks from overseas, exchanging them for rubber masks in use in the zone of interior, and shipping the latter in turn to the reconditioning plants for ultimate use overseas. The reconditioning program also played a part in supplying a substitute for the hoseless M5 combat mask withdrawn from production in 1944. In the summer of 1945 the gas mask industry began turning out the M3-11-10 snout-type mask, in which the assault-type M11 canister was attached directly to the front of a reconditioned rubber facepiece. Over 300,000 of these masks were produced before V-J Day halted the assembly lines.[30] The M8 snout-type mask was the last of the series of masks produced during the war for general issue to troops.

[28] (1) History of the Dallas CWPD, 1 Jul 44-14 Aug 45, p. 31. (2) Minutes of Weekly Meeting, Office of Assistant Chief, CWS, for Materiel, 31 Aug 44. CWS 314.7 Gas Masks File.

[29] CWTC Item 1339, 24 May 45, Standardization of Facepieces, Service, M4 and M4A1.

[30] (1) Ltr, TAG to CG's of Service Commands, MDW, and C CWS, 11 Apr 45, sub: Survey of Gas Masks in Service Command Posts, Camps, and Stations in the Continental United States. (2) Memo, Dir Requirements and Stock Control Div ASF for ASF Directors, 17 Jul 45, sub: Supply Control of Gas Masks. Both in ASF 470.72. (3) Weekly Report of Activities, OC, CWS, week ending 20 Jul 45. (4) History of the Boston CWPD, vol. 9, pp. 152-59.

Special Purpose Masks

The production history of the gas mask program would not be complete without reference to the special purpose masks manufactured by the CWS or its contractors between 1940 and 1945. In terms of magnitude, the most important of these special programs was the one for the diaphragm mask. Although this item was never entirely satisfactory, the CWS hoped that eventually a greatly improved diaphragm mask would come off the assembly line. Plans in May 1942 called for supplying the Army with five million or more of these masks.[31] A program of this size obviously required the participation of industry. Edgewood Arsenal alone produced two million diaphragm masks in the two years between February 1941 and March 1943. By the latter date plans for industrial production were complete, and the first diaphragm masks to be turned out by private contractors were accepted in April 1943.[32] But by June this type of mask was rejected by the using arms and production was stopped.[33]

The program for the optical mask was less ambitious. Edgewood Arsenal turned out about 116,000 in mid-1941, and no further production was undertaken for three years. Then in 1944, in response to an ASF demand, the CWS undertook to produce another ninety thousand though it had not yet completed development of the item. The development laboratory provided a master form for the facepiece, and the rubber blanks were manufactured by the Sun Rubber Co. of Barberton, Ohio, after an attempt by the Acushnet Process Co. of New Bedford had demonstrated that neoprene would not meet requirements. The masks were assembled by a Chicago district contractor, Eureka Vacuum Cleaner Co. of Detroit.[34] An optical mask developed and requisitioned by the Navy was produced on short notice in 1943-44 by the New York district, despite the fact that the district had not shared in the CWS gas mask program except for its part in the nationwide procurement of noncombatant masks.[35]

Procurement of such other special purpose masks as were not turned out solely by the CWS pilot plant at Edgewood Arsenal was generally accomplished through the Boston Procurement District. The headwound mask was produced in the district for a short time in 1944-45, with the Firestone Co. of Fall River making the final assembly. Facepieces for col-

[31] WD SOS Army Supply Program, Monthly Status Report CWS Equipment Section, No. 4, May 1942.

[32] CWS Report of Production, 1 Jan 40 through 31 Dec 45.

[33] History of the Boston CWPD, vol. 9, p. 118.

[34] History of the Pittsburgh CWPD, pp. 175-77.

[35] History of the New York CWPD from 1940 through June 1944, vol. 1, pp. 225-50.

lective protectors were also procured in 1944–45, the prime contractor being the Electrolux Co. of Old Greenwich, Conn. This company, which had taken part in the development of the item, continued to assemble facepieces until the war ended.[36]

Inspection of Gas Masks

At the start of the war the CWS had compiled very little literature to assist its inspectors in carrying out their day-to-day operations. To fill this need the Inspection Division, OC CWS, inaugurated the practice of writing a Standard Inspection Procedure (SIP) for each CW end item. The SIP described the item and its use, how it was made, and how it functioned. It went on to specify the parts of the item to be inspected, the tools or instruments to be used in carrying out the inspection, and it finally outlined such matters as proof testing, surveillance procedures, and packaging. The bulk of the SIP's on the CW items were prepared and circulated by the summer of 1944.[37]

The SIP on the gas mask which the Inspection Division wrote in 1943 called for end-item inspection by the government of each lot of masks coming off the assembly line. If the CWS inspector rejected a lot the contractor's inspectors had to recheck each mask in that lot. All defective masks then had to be reworked. Later the CWS modified this procedure by having its inspectors check the masks as they were moving along on the conveyor line, and if the CWS inspector rejected a certain number, the contractor's inspectors reinspected all the masks remaining on the line. Meanwhile the contractor held up all production until the particular defect was eliminated. The latter system proved more satisfactory than the former because it prevented the incorporation of undesirable features into the mask.

After World War II the contractors who had assembled gas masks during the war almost invariably complained of the CWS system of inspection. Their complaints came under two headings: first, that the inspectors by and large were inadequately trained, and secondly, that the 1943 SIP was impractical for purposes of quantity, and simultaneously quality, production of gas masks.[38] While many gas mask inspectors were doubtless deficient in background and insufficiently trained, this complaint was perhaps too sweeping. The condition was partially the result of the tight labor

[36] History of the Boston CWPD, vol. 9, pp. 160–65, 179–86.
[37] Annual Report of Inspection Division, OC CWS, for Fiscal Year 1944.
[38] Planning Study, Mask, Phase I, pp. 87–90, and vol. VII, p. 124. ETF 611.69–2/2.

market existing at that time. The second complaint would also seem to have a basis in fact. When the government took the position that there should be a 100 percent of inspection of certain munitions—and such insistence was unquestionably legitimate— it could not at the same time consistently place primary emphasis on mass production of the item. It was mass production, plus haste in designing masks and components, that was at the root of the difficulty. The fact that there were many minor discrepancies in specifications and acceptance standards for components from different suppliers tended to produce rejections of finished masks for causes beyond the control of the end-item assembler.

Production of Impregnite (CC-2)

The plant for producing the impregnite CC-2 which the CWS built at Edgewood Arsenal in the 1930's began to operate on a production basis in October 1940. Among the plants it erected at Edgewood in the emergency period, the CWS included a new impregnite plant utilizing a new process of manufacture. This plant got into production early in 1942. The two Edgewood plants continued to operate until the start of 1943. Meanwhile, the plant at Niagara Falls got into operation in the fall of 1941 and in early 1942 the plants at St. Louis and Midland.[39]

A number of manufacturing difficulties soon presented themselves. At the Niagara Falls plant, corrosion of equipment by the highly reactive materials used in the process became a major problem, so much so that Du Pont made it the subject of an extended research project during 1942. Early production yields were disappointingly small when measured against the yields known to be available. Furthermore, the quality of the product left much to be desired. Batch after batch failed to meet specifications and had to be washed free of impurities if not reprocessed altogether. By March 1942, when the Du Pont plant had been over five months in operation without a substantial advance in yield or quality, the CWS was voicing concern.[40] Production ills were meanwhile besetting the Midland and St. Louis plants, operated by Dow Chemical Co. and Monsanto Chemical Co., respectively. But in the months that followed, the results of accumulating experience and production research began to tell. By the late

[39] (1) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 18. (2) History of Edgewood Arsenal in World War II, vol. II, pp. 556–57. (3) History of Niagara Falls CWS Plant, p. 1. (4) Pamphlet, "Performance Record of the Dow Chemical Company in the War Effort," 9 Jan 45 (Historical Account), p. 30.

[40] (1) Niagara Falls CWS Plant Reports, Sep 41–Mar 42, Incls to Historical Material. (2) Notes of conference held by General Porter, 13 Mar 42. CWS 337.

autumn of 1942 the plants were approximating their rated capacity of five tons per day apiece, and the worst difficulties were past. In 1943 the rated capacity was substantially exceeded by actual production of specification-grade material.[41]

In the impregnating process CC-2 was dissolved in acetylene tetrachloride, a highly toxic solvent. Since the use of such a solvent was both difficult and dangerous, officials placed a requirement for a water soluble impregnite. Technicians met this need by reducing the individual particle size in CC-2 to micron proportions. Production of micronized CC-2, redesignated XX-CC3, began in the spring of 1943 after the installation of micronizing equipment in the plants. During the next eighteen months the greater part of the CC-2 turned out was converted at the plant to XX-CC3. At the beginning of 1944 the impregnite plants were delivering 700 tons of impregnite a month to the CWS.[42] With the peak period of military build-up already past, the CWS had to plan early cutbacks in output. In March 1944 the ASF authorized the CWS to place the Midland plant on standby status and to reduce production in the remaining two plants. By May impregnite production was accordingly down to a level approximating 250 tons per month. Micronizing operations were halted entirely by the CWS after October 1944, but CC-2 production was increased somewhat in the early months of 1945. Production continued until hostilities ended. From first to last, over 18,000 tons of impregnite were produced for the CWS between 1940 and 1945.[43]

Procurement of Impregnating Plants

As important as the development of the protective clothing was the problem of maintaining a global supply of the item against the threat of gas warfare. Large stores of protective clothing had to be kept in readiness in all theaters of war and maintained in effective condition. Since the protective capacity of CC-2 in clothing gradually diminished with long storage and deteriorated even more rapidly when the clothing was in use, a kit had to be developed to assess the CC-2 content of protective clothing.[44] Rapid resupply of storage stocks which might be called for issue

[41] (1) Niagara Falls CWS Plant Reports, Nov 42–Nov 43, Incls to Historical Material. (2) "Performance Record of the Dow Chemical Company," p. 31. (3) History of the St. Louis CWS Plant, p. 2.

[42] (1) Niagara Falls CWS Plant Reports, Apr–Nov 43, Incls to Historical Material. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45.

[43] (1) Memo, Maj Gen Lucius D. Clay to USW, 25 Mar 44, sub: Request for Approval of Cutback in Production of Impregnite "I." Files of Dir Materiel ASF. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45.

[44] CWTC Item 690, Standardization of Kit, Testing Impregnite in Clothing, M1, 23 Apr 43.

on very short notice demanded the installation of impregnating facilities at storage points both at home and abroad. With the outbreak of gas warfare, vast quantities of contaminated clothing would have to be decontaminated and laundered, with consequent diminution of its CC-2 content. This potential need made it imperative that large-scale semifixed plants be developed and installed near resupply points.

Three types of impregnating plants, based on American Laundry Machine Co. models, were developed and standardized by 1943: (1) The M1 plant (zone of interior), a fixed type with a capacity of 9,000 units of clothing each 24 hours; (2) the M1 plant (theater of operations); and (3) the M2 plant (theater of operations), which was a semifixed type with a capacity of almost 4,000 pounds per 24-hour day or 13,300 sets of clothing weekly. Both of the M1 plants were designed for the standard solvent process of impregnation in which CC-2 and chlorinated paraffin as a binder were dissolved in acetylene tetrachloride, applied to the clothing by uniform saturation, and the solvent then evaporated.[45]

The size and weight of M1 impregnating equipment presented difficulties in zone of interior installations, and in theater of operations plants gave rise to major problems. Theater plant equipment included two 400-gallon solution tanks; three modified laundry washing machines, two with solvent recovery units; a modified laundry washing machine, called the impregnator; a steam generating unit; an electric generating unit; and various auxiliary items such as fuel tanks, pumps, and tools. Depending upon the model the packed plant weighed from 80,000 to 105,000 pounds and was approximately 6,000 cubic feet in volume. Thirteen vehicles were required for its transportation. Skid mountings and special packings were developed to facilitate handling.[46]

Each zone of interior M1 plant cost $358,000 and each theater of operations M1 plant approximately $79,000.[47] A total of thirty-four M1 theater of operations plants was procured in 1942 and 1943 from the American Laundry Machinery Co. and Proctor and Schwartz, Inc., under the super-

[45] (1) CWTC Item 344, Standardization of Impregnating Plant (T of O), 27 May 41. (2) CWTC Item 761, Standardization of Plant, Impregnating (Z of I), M1, 23 Jul 43. (3) Ltr, Clarence E. Trotter, Manager, Special Projects, American Laundry Co. to Hist Off, 25 Apr 58. With this letter is an inclosure signed by Russell A. Hetzer, Chief Engineer, who worked on the impregnating plant program in World War II. CWS 314.7 Impregnating Plants File.

[46] TM 3-270, 4 Feb 44.

[47] Draft table, Dollar Volume of CWS Procurement, Protective Material, in folder, Unit and Dollar Summaries, Protective Storage and Issue, 1 Jul 40–31 Dec 45. CWS 314.7 Procurement Statistics File.

vision of Edgewood Arsenal and the New York procurement district. Two M1 zone of interior plants were procured.[48]

The M2 plant used a water suspension method, developed in 1942 by a group under Dr. P. L. Salzberg at the Du Pont chemistry laboratories, involving micronized CC-2, chlorinated paraffin, and suspension and dispersing agents. This process, through the elimination of the toxic solvent, was simpler, safer, and more economical than the solvent process and was standardized for both the Army and Navy in mid-1943.[49]

Although clothing treated by the new aqueous method proved highly satisfactory when worn in temperate climates, in the tropics the clothing caused excessive skin irritation to troops wearing it for long periods of time. The hazard was traced to the zinc oxide stabilizer that had been incorporated in both the solvent and suspension processes by the Du Pont group to prevent deterioration of impregnated cotton clothing in storage in the tropics. The CWS withheld issue of the M2 plant from Pacific theaters until researchers found that replacing the stabilizing agent zinc oxide with calcium carbonate eliminated the hazard without affecting the storage life of the clothing.[50]

The M2 plant was less complicated than the M1 and was considerably less expensive to procure, the cost being about $47,000 per plant.[51] The packed plant weighed from 10,000 to 30,000 pounds less than the M1, but the volume was 500 cubic feet greater principally because of the addition of a large but lightweight solution mixing unit. The M2, like the M1, required a firm foundation of timbers or concrete and a weatherproofed shelter.[52] In 1942 Edgewood Arsenal produced one M2 plant and in the following year the CWS procured ninety-four additional M2's from the American Laundry Machinery Co.[53]

The major portion of these M2 plants replaced M1's or provided initial equipment for the thirty-nine processing companies activated between 1941 and 1945. All but one of these companies saw service overseas.[54] In the absence of gas warfare, the companies were given secondary missions, in

[48] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 25.

[49] (1) CWTC Item 756, Standardization of Plant, Impregnating, M2, 23 Jul 43. (2) Chemical Warfare Board Project No. 289, Field Test of Plant, Impregnating, M1, 20 May 43. (3) Noyes, *Chemistry*, pp. 206–07.

[50] CWTC Item 1246, Issue of Plant, Impregnating, M2, 26 Oct 44.

[51] Draft table, Dollar Volume of CWS Procurement.

[52] TM 3–281, 10 Feb 54.

[53] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 25.

[54] See Brophy and Fisher, *Organizing for War*, app. H–11.

addition to their primary function of maintaining theater stocks of impregnated clothing, of providing dry cleaning (the M1 plant) and laundry services to troops in the field. Once a suitable water supply was located the equipment was easily adapted to these tasks. In the tropics and semitropics the equipment was put to good use in impregnating clothing with insecticides as a preventative for scrub typhus and malaria.[55]

To provide advance company units in the field with means for impregnating clothing in an emergency, Dr. Salzberg's group developed a small field set weighing 52 pounds, capable of processing 24 suits of clothing.[56] Finally, a helmet impregnating set, to be carried in the pack or gas mask carrier and weighing less than half a pound, was experimented with to permit the individual soldier to impregnate his uniform, shorts, and socks, using his helmet and water from his canteen. A later requirement for a highly mobile unit capable of handling 1,400 pounds of clothing (approximately 200 suits) each 24 hours was relinquished when it was found that the Quartermaster mobile laundry units in the field could be adapted, by means of a special kit, as temporary water-suspension impregnating plants.[57]

Next to the gas mask, protective clothing was the soldier's most important defense against gas warfare and every individual moving overseas received a complete issue. In the theater of operations this individual issue was maintained either in the hands of the soldier or in readily available supply locations. In addition, theater reserves were stocked in the early part of the war on a 100 percent reissue basis and later in the war on a descending scale according to the vulnerability of each area to the initiation of gas warfare. Protective clothing was actually worn in operations in which the enemy's initiation of gas warfare appeared possible, such as the Normandy invasion.[58]

Protective Ointment [59]

The CWS awarded a development contract on protective ointment, the antigas decontaminant for use on the soldier's body and personal weapons,

[55] See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[56] CWTC Item 766, Standardization of Set, Impregnating, Field, M1, 23 Jul 43.

[57] (1) Chemical Warfare Board Project No. 298, Test of Mobile Water Suspension Impregnating Plant, 31 Aug 43. (2) CWTC Item 863, Military Requirements and Military Characteristics for a Mobile Impregnating Unit, 3 Dec 43. (3) CWTC Item 993, Military Requirement and Military Characteristics for a Kit for Conversion of Mobile Laundry Units for Impregnation, 5 May 44. See also Item 1090, 7 Jul 44, same title.

[58] See Brophy and Fisher, *Organizing for War*, ch. IV, and Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[59] Unless otherwise indicated, this section is based on the following: (1) Wallace and Tiernan

to Wallace and Tiernan Products, Inc., in February 1941.[60] Under that contract the company produced M1 and M2 ointment on a pilot plant basis until September when it suspended production in order to put the knowledge and experience gained into practice. Wallace and Tiernan set up a manufacturing plant for M1 ointment in one of its buildings in Belleville, N.J., and this plant was operating in December 1941. In the fall of 1941, meanwhile, the CWS awarded a research contract to Evans Chemetics, Inc., of New York City. This was followed by a production contract in January 1942. To manufacture the ointment Evans Chemetics built a plant in Hoboken, N.J.

The M1 was unlike any ointment that had ever been produced commercially. One of its chief ingredients was chlorine, which reacts adversely on ordinary production equipment. The nature of the ingredients made it difficult to obtain a uniform mix and it was impossible to pump this mix from the kettle to the tube filling machine. To overcome these difficulties, Wallace and Tiernan, the first contractor in production, developed glass lined kettles and power driven agitators to mix the ingredients, used inert metals such as platinum or tungsten for valve seats, valve stems, and metallic parts of tubing machines, installed an air pressure transfer system, and devised glass and ceramic piping to carry the mix from the kettle to the tube filling machine.

Another serious complication encountered in early manufacture was that the lead tubes into which the ointment was filled contaminated the product. Tubes made from aluminum or even from tin would have been preferable, but those metals were in short supply. The Dewey and Almy Chemical Co., Cambridge, Mass., developed a satisfactory lining for the tube, consisting of a combination of wax and synthetic rubber. This tube was put into production by several manufacturers, including the Peerless

Products, Inc., CWS Production in World War II, an account written in Oct 44 by a representative of the company at the request of CWS. CWS 314.7 Industrial History and Procurement File. (2) Interv, Hist Off with C. W. MacFarlan, 26 Feb 57. Mr. MacFarlan worked on development of protective ointment for the CWS before and during World War II. (3) Interv, Hist Off with Paul A. Longo, 29 Apr 58. Mr. Longo worked on production of the ointment in the New York procurement district. (4) Interv, Hist Off with Dr. Henry C. Marks, Wallace and Tiernan Co., 27 Nov 57. Dr. Marks worked on the protective ointment program before and during World War II. (5) Ltr, Dr. Henry C. Marks to Hist Off, 10 Dec 57, implementing points discussed in interview of 27 Nov 57. (6) Interv, Hist Off with Dr. Ralph L. Evans of Evans Research and Development Corp., formerly Evans Chemetics, Inc., 4 Mar 58. Evans Chemetics was an early protective ointment contractor. (7) Interv, Hist Off with Joel Y. Lund, 29 Apr 58. Mr. Lund supervised the ointment program at Lambert Pharmacal Co.

[60] Progress Report Covering Experimental Work Under Contract No. 266-CWS 120, February 1, 1941, to December 31, 1941, submitted by Research Department of Wallace and Tiernan, Inc. ETF 615 W-11a.

Tube Co., Bloomfield, N.J., and the Sun Tube Co., a subsidiary of the Bristol Myers Co., Hillside, N.J.[61] In August 1942 the CWS contracted with a third firm to produce the ointment, the Lambert Pharmacal Co., St. Louis, Mo. This company, which continued in production until November of the following year, produced more ointment than either of the other contractors.[62]

In the fall of 1943 the NDRC began sponsoring conferences between manufacturers of the ointment and representatives of the CWS and the Navy. One of the chief objectives of the conferences was improvement in the packaging of the ointment. As a result of these conferences the contractors generally became much freer in exchanging ideas on all phases of the program. This they generally did through telephone calls or visits to one another's plants.

An outstanding accomplishment connected with the procurement of the ointment was the development of an excellent brand of triacetin, an ingredient of glycerol triacetate, by the Tennessee Eastman Co. of Kingsport, Tenn. This company produced a high grade product and sold it to the manufacturers of the ointment at a reasonable price. The same company also furnished the cellulose acetate butyrate used in the ointment.

From February 1941 until December 1943 the CWS procured over 58,000,000 2.54-ounce tubes of M4 ointment and from May 1944 until June 1945 over 26,000,000 packages, each containing 4 ¾-ounce tubes of M5 ointment.[63]

Detector Kits[64]

The CWS procured over 40,000 M4 vapor detector kits for detection of toxic agents in 1942 through contracts in the New York and Chicago procurement districts. No unusual problems arose in the procurement of this relatively simple item. In mid-1943, as indicated elsewhere, the M4

[61] Bristol Myers Company made BAL for the Medical Corps in World War II. See Civilian Production Administration, Industrial Statistics Division, *Alphabetic Listing of Major Supply Contracts, Cumulative, June 1940 through September 1945,* vol. 1, p. 495.

[62] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 24.

[63] Crawford, Cook, and Whiting, Statistics, "Procurement," p. 23 and CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 19, 24.

[64] This section is based on: (1) History of the Chicago CWPD, 1 Jan 45–15 Aug 45, pp. 68–69. (2) Evans interv, 4 Mar 58. (3) Interv, Hist Off with Raymond Reed, Chief of Research for Raymond Laboratories, St. Paul, Minn., in World War II, 14 Mar 58. (4) CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 18–19. (5) David Tenenbaum, Chemical Agent Detector Kit, M9, History of Development Work at Raymond Laboratories. CWS 314.7 Procurement File.

was replaced by the M9, a kit containing nearly 200 small tubes of reagents for detection of various war gases.[65]

The M9 proved much more difficult to produce than did the M4. As one of the chief wartime contractors later put it, "this item was typical of the new development, characterized by immature specification." [66] Commercial laboratories continually face situations such as this in day-to-day operations, but they do not attempt to put items into full-scale production until the items have reached an advanced state of development. With government wartime contracts it was different. The M9 kit was but one of a number of items on which the CWS awarded production contracts before mature development had taken place.

The CWS awarded contracts in the summer of 1943 to two firms for production of the M9 kit, Evans Chemetics, Inc., of New York City, and Raymond Laboratories, Inc., of St. Paul, Minn. Because of the stream of specification changes which the CWS laboratory at MIT issued on the various items in the kit, neither contractor was able to produce a single finished kit for at least six months. Meanwhile, both contractors had devised methods for mass production, set up assembly lines, and made valuable suggestions relative to certain features of the kit. Raymond Laboratories was particularly prolific with suggestions. In peacetime this company had manufactured appliances for beauty parlors and it applied some of its experience with this type of item to the production of the M9 kit. For example, original specifications called for the use of lighted matches as a source of heat for producing chemical reactions. On the basis of its experience in making heating pads for waving hair, Raymond Laboratories suggested the use of a foil wrapped pad which would produce flameless heat upon the addition of a liquid chemical. This suggestion the CWS gladly accepted. Again, original specifications called for packing the small glass tubes of reagents in cellophane straws and then sealing the ends of the straws by a heating process. Raymond convinced the CWS to substitute aluminum foil for cellophane. Finally, at the suggestion of Raymond Laboratories, the CWS made several changes in the design of the air sampling pump of the detector kit.

The CWS procured over eighty-two thousand M9 kits between April 1944 and July 1945.

[65] See ch. IV above.
[66] Reed interv, 14 Mar 58.

Decontaminating Apparatus [67]

In carrying out its gas readiness program the Army was able to find no quicker or more effective destroyer of liquid mustard or contaminated areas or structures than the bleaching powder or chloride of lime used in World War I, and large quantities of it were stored in depots here and abroad as part of the Army's gas warfare readiness program. The CWS procured over thirty-eight million pounds of bleaching material through private contract and obtained over thirty-one million more from the British on reverse lend-lease.[68] The American bleach (known as Grade 3) which the CWS first procured had a high moisture content which caused chemical reaction leading to rupture of the containers. The British product, known as super tropical bleach, developed by the Imperial Chemical Industries, was a much more satisfactory product. The U.S. Government arranged to have the British Imperial Chemical Industries assist the Pennsylvania Salt Manufacturing Co., which supplied bleach to the CWS, to construct a plant for the manufacture of tropical bleach at Wyandotte, Mich. This plant had been built and in production only a short time when a fire destroyed it in August 1944. Since the U.S. wartime requirements had been met by that time the CWS let no further contracts for bleach.[69]

For decontaminating vehicles, planes, weapons, fire control apparatus, and similar finished metal surfaces, DANC, the standard *d*econtaminating *a*gent, *n*on-*c*orrosive, was used.[70] Because this decontaminant caused some damage to paint, plastics, and bare metal surfaces and because there were objections to the toxic solvent in its composition, the NDRC at the request of the Naval Research Laboratory initiated a contract study under J. E. Kirby of the Du Pont Laboratories to find a better agent. No clearly superior decontaminant was developed.[71]

[67] Unless otherwise indicated the section on power-driven decontamination units is based on: (1) History of the Pittsburgh CWPD, pp. 228–34; (2) History of Chicago CWPD, 1 Jan 45–15 Aug 54, p. 70; (3) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 2; (4) Hinckley interv, 9 Jan 58; (5) Interv, Hist Off with Col Carl Casto, 17 Apr 58; Casto was chief of the Edgewood Arsenal Inspection Off in WW II, which inspected the power-driven decon apparatus and made numerous suggestions for its improvement; and (6) Interv, Hist Off with Ferdinand J. d'Eustachio, 24 Apr 58. Mr. d'Eustachio worked on the inspection and engineering problems of the decon apparatus in World War II.

[68] Consolidated Chemical Commodity Report, 16 Oct 51, p. 67.

[69] Memo, 1st Lt E. F. Lennon to Chief, Chemical Section, Industrial Division, OC CWS, 14 Aug 43, sub: Report of Visit to Chicago CWPD and Penn Salt Mfg Co. CWS 314.7 Procurement File. (2) Interv, Hist Off with Maj Eugene F. Lennon, Jr., 27 May 58. Lennon was in the Chemical Commodity Division in World War II.

[70] DANC was a solution of a chemical compound known as RH 195 in acetylene tetrachloride.

[71] Noyes, *Chemistry*, pp. 184–87.

The CWS modified fire extinguishers and garden sprayers for the application of DANC, and adapted commercial orchard sprayers for the discharge of volumes of bleach water mixtures (slurry) over large contaminated areas. Every vehicle going overseas was equipped with a 1½-quart decontaminating apparatus and every company in the Army was furnished a 3-gallon unit. The Army issued power driven apparatus to CWS decontaminating companies and to the Armored Force and Air Force squadrons.

In the spring of 1941 the CWS contracted with the F. E. Myers and Brothers Co., Ashland, Ohio, a manufacturer of pumps and orchard sprayers, for six power driven models. On the basis of these models, which the company delivered in June 1941, the CWS wrote specifications for the power driven decontaminating apparatus. After the outbreak of war the Myers Co. continued to manufacture the item. In March 1942 two additional companies, Friend Manufacturing Co., Gasport, N.Y., and John Bean Manufacturing Co., Lansing, Mich., got into production. Later A. B. Farquhar of York, Pa., was awarded a contract. These companies found the item so difficult to manufacture that the CWS Inspection Division deemed it advisable first to approve numerous changes in the specifications and eventually to authorize a performance-type specification for the item.

The apparatus (M3 and M3A1) which these companies manufactured for the CWS in 1942 and 1943 consisted of a 400-gallon wooden tank mounted on a 2½-ton truck with a pump and slurry agitator powered by a take-off from the engine of the truck. It was capable of spraying 400 gallons of the mixture in twenty minutes.[72] For more efficient spraying a separate portable water heater was furnished in 1943.[73] Each manufacturer applied a pump of his own design to the apparatus which in effect put four models instead of one into the supply system. The item went into production before the CW Board had carried out extensive tests on the possible corrosive effects of the slurry. Upon investigation the board found that the slurry corroded not only the wooden tanks but also the pumps. The tanks could be cleaned—a difficult task to be sure—but there was nothing left to do with regard to the pumps but to require that they be made of noncorrosive materials. Friend Manufacturing Co. already had a pump with ceramic cylinder lining which was satisfactory. But Myers, Bean, and Farquhar had to change their pumps, an undertaking that proved onerous because of low CWS priorities. After the introduction of the hot bleach system it was found that the rate of corrosion became much more

[72] TM 3-221, 15 Apr 43, p. 3.
[73] TM 3-228, 15 Aug 44, p. 1.

rapid. The practice of heating the slurry was nevertheless desirable since, as already indicated, it made for a much more effective spray. In fact in cold weather heating the liquid was a necessity.

The Quartermaster Corps and later the Ordnance Department furnished the trucks on which the apparatus was mounted. Ordnance experienced so much difficulty procuring these trucks that in the spring of 1943 the CWS standardized a skid mounted apparatus (M4).[74] As its name indicates, this model was constructed on skids, and in such a manner that it could be hauled on a 2½-ton truck. The apparatus, with pump and agitator powered by a 22-horsepower gasoline engine, could spray the contents of its tank for about twenty minutes.[75] As with the previous model, each manufacturer of the skid mounted apparatus, proceeded to make his own type of pump. In procuring this new apparatus the CWS was faced with the problem of obtaining an engine to run the apparatus pump, because with the elimination of the truck engine, the system of power takeoff was also eliminated. Three of the companies had no trouble obtaining motors of the Continental and Novo variety, but the fourth, A. B. Farquhar, did experience difficulty. For a time the Ordnance Department supplied Ford motors that Farquhar could use, but that source of supply soon dried up. Following a suggestion of the Farquhar Co., the CWS approached Sears, Roebuck and Co. with a request to supply Ford motors. But Sears furnished only Ford blocks into which parts had to be assembled. To accomplish the latter task, the CWS awarded a contract to a St. Louis firm which scoured every conceivable source of supply—junk yards, secondhand stores, auto supply stores—for parts and assembled them into the blocks. These rebuilt motors were shipped to Farquhar and incorporated into the decontaminating unit.

Discouraging though this procurement program was, the CWS might have continued with it but for general dissatisfaction with the skid mounted apparatus. No one liked its lack of mobility. By 1943, moreover, complaints were coming in from the theater on the lack of interchangeability of the parts of the various apparatus. The CWS therefore decided to standardize the most satisfactory truck mounted model, the unit produced by John Bean Manufacturing Co. From that time until the close of hostilities Bean was the sole manufacturer of power driven decontaminating apparatus.[76]

Few pieces of CWS equipment saw so much application overseas as

[74] CWTC Item 701, 23 Apr 43.
[75] TM 3-222, 5 Feb 44, p. 1.
[76] This model was the M3A2. See TM 3-223, 26 Jul 44.

did these large decontaminating units. In the absence of gas warfare they were used as emergency fire fighting apparatus, water haulers, field showers, high pressure equipment cleaners, and later as large-volume spray apparatus in insect control operations. Both the hand operated decontaminating apparatus and the M10 airplane spray tank were also used to spray insecticides.

The 1½-quart hand decontaminator, M2, was essentially a modified commercial fire extinguisher. Several concerns, notably the Fyr-Fyter Co. of Dayton, Ohio, General Detroit Corp. of Detroit, and the Badger Fire Extinguisher Co. of Somerville, Mass., produced the item for the CWS during the first years of the war. There were difficulties in connection with the heavy consumptions of brass sheets and strips required for the M2. Copper and copper alloys were critical items, and the ASF would have welcomed a decontaminator constructed of other materials. But though such an item had reached the design stage by 1943, it did not get into production before the program ended. A major problem, both in the production model and the testing of substitutes, was the corrosive character of the decontaminating material with which the M2 was charged. Pyrex valves replaced steel because of this factor, and new spray nozzles and valve seats had to be designed. Total production of the M2 hand decontaminators reached a rate of over one hundred and thirty thousand per month in the spring of 1943, and more than a million had been turned out when the program was terminated in October of that year. Limited production was resumed early in 1945 and continued until the end of the war.[77]

The 3-gallon decontaminating apparatus, M1, like the power driven types, was adapted to CWS purposes from an agricultural sprayer. Again, the corrosive nature of the charge made certain design and material changes necessary. More than two hundred and seventy-five thousand M1 decontaminators were procured from industry by the New York and Chicago procurement districts between 1941 and 1943.[78]

Miscellaneous Protective Items

In 1938–39 the CWS, in co-operation with the Vortexol Co., Sangus, Mass., developed an impregnite to protect shoes against toxic agents. In

[77] (1) History of the Boston CWPD, vol. 7, pp. 61–65. (2) History of the Chicago CWPD, 1 Jan 45–15 Aug 45, pp. 79–81. (3) History of the Pittsburgh CWPD, pp. 245–47. (4) Memo, Col J. E. Butterworth to Requirements Br ASF, 2 Apr 43, sub: Brass Sheet and Strip for Apparatus, Decontaminating, 1½ quart. CG, ASF, 475.9 Equipment, CWS. (5) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 2.

[78] (1) History of the Chicago CWPD, 1 Jan 45–15 Aug 45, p. 81. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 2.

the summer of 1940 the chief's office awarded an educational order contract on shoe impregnite to Baldwin Laboratories, Seagerstown, Pa., a subsidiary of Robinson Industries, Inc. This educational order provided for the contractor (1) to prepare a factory plan and design for CWS approval, (2) upon approval of this plan to procure and install necessary equipment for the manufacture of the item, and (3) to produce 125 tons of the product during a 25-day period in order to prove the design and capacity of the plant. This contract proved very successful and Robinson Industries became one of the chief wartime producers of shoe impregnite. Not only did this concern produce a high grade product, but it also paid close attention to plant safety and co-operated in an exemplary manner with later contractors. Among the most successful of these were the Ernest Bischoff Co., Inc., which manufactured the product at its Memphis, Tenn., plant, and the National Oil Products Co., which produced the material at its Cedartown, Ga., plant. Over seventy million 8-ounce cans of shoe impregnite were procured.[79]

The CWS procured over six and a half million dust respirators in World War II.[80] This item, which was designed to protect drivers of heavy vehicles from dust, consisted of a faceblank with a layer of filtering material, webbing, and inlet and outlet valves. The most critical component was the facepiece, which was manufactured by some half dozen rubber companies and which, because of its peculiar design, gave rise to several molding problems. Another difficulty that arose was the tendency of the respirator to build up high air resistance. This condition was caused by the type of cloth filter material used, and to overcome it the CWS modified the filter material.[81]

To satisfy the Army demand for eyeshields the CWS procured almost 72,000,000 of them through private contracts.[82] The eyeshield consisted of a cellulose acetate sheet (which was either clear or tinted), impermeable cloth, webbing, and metal hardware. The cellulose acetate sheeting and impermeable cloth were die cut and the webbing and hardware assembled to these components. The assembly process was relatively simple. The eyeshields were packaged in packets of 4—2 clear and 2 tinted.[83]

[79] (1) History of the Boston CWPD, vol. 7, pp. 58–60. (2) History of the Pittsburgh CWPD, pp. 208–15. (3) Crawford, Cook, and Whiting, Statistics, "Procurement," p. 22.

[80] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 26.

[81] (1) History of the Boston CWPD, vol. 7, pp. 1–9. (2) Ltr, Paul A. Longo to Hist Off, 15 Apr 58. Mr. Longo assisted in the administration of the dust respirator and eyeshield programs in the New York Procurement District in World War II.

[82] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 12.

[83] *Ibid.*

Other miscellaneous protective items which the CWS procured under contract were gas resistant aprons, made of impermeable cloth and intended for use by certain Medical Corps and CWS troops; gas resistant sacks for shipment of contaminated clothing to decontaminating stations; and various items for detecting such gases as vesicant detector crayons and liquid vesicant detector paper and paint.

Most of the defensive items which the CWS procured were intended for protection against gas warfare, although certain of them such as the decontaminating apparatus and the eyeshield proved useful in nongas warfare situations. Most offensive items, on the other hand, were intended for nongas warfare uses. These included such weapons as the incendiary bomb, the smoke generator, and the flame thrower, all of which the service procured in great numbers. The CWS also procured a considerable number of 4.2-inch chemical mortars and shells. The mortar, though originally designed to fire toxic shells, was used during the war to fire high explosives.

Problems of manufacture of CWS defensive items sprang chiefly from the attempt to put items that had not been fully developed into mass production. Of all these items the gas mask had been developed to the greatest degree, yet the pressure to produce new models during the war gave rise to many manufacturing difficulties. Such items as protective ointments, detector kits, and decontaminating apparatus were at primitive states of development when the CWS awarded production contracts for them. Development of these items proceeded simultaneously with their production.

CHAPTER XV

Procurement of Offensive Matériel

Among the offensive munitions which the CWS procured in World War II were incendiaries of various types, 4.2 inch mortars and shells, flame throwers, smoke, and smoke munitions.

Incendiaries

The M54 Thermate Bomb

Even before the Secretary of War officially notified the Chief, CWS, of his responsibility for the entire incendiary bomb program,[1] General Porter was authorized on 28 August 1941 to procure over twenty-five million 4-pound incendiary bombs with magnesium bodies at a cost of something under $50,000,000. On 20 September, after a decision by the General Staff, procurement of fifteen million more bombs was approved, bringing the aggregate to forty million incendiary bombs.[2] General Porter took immediate steps to obtain these bombs, assigning direct responsibility to Col. Joachim E. Zanetti whom he appointed chief of a newly activated Incendiaries Branch, Technical Service, OC CWS.[3] After surveying a number of industrial facilities the CWS began awarding contracts for the assembly and filling of the bombs as well as for the procurement of metal components.

On the very day that Pearl Harbor was attacked The Adjutant General telephoned General Porter's office and advised that over sixty-nine

[1] See ch. VIII above.

[2] Memo, ExO Contl Div, OC CWS, for C CWS, 30 Nov 42, sub: Chronology of Events on Requirements of 4-lb Incendiary Bomb. CWS 314.7 Incendiary File.

[3] Organization Chart, OC CWS, 18 Sep 41.

million dollars still available to the Chief of Ordnance from funds originally estimated for the incendiary bomb program would be suballotted to the Chief, CWS. Before another two weeks elapsed contracts for assembling and filling twenty million incendiary bombs had been awarded to thirteen contractors throughout all the various procurement districts.[4] Construction of new manufacturing and loading facilities for incendiaries was meanwhile progressing at Pine Bluff and Huntsville Arsenals. Actual requirements for the 4-pound incendiary, as covered by the first supplemental appropriation act, Fiscal Year 1942, totaled over seventy-four million bombs, but since there was no possibility of obtaining magnesium, the steel body thermate bomb (M54) had to be substituted. For this reason the Office of the Under Secretary of War had held the requirements for the time being to twenty million bombs.[5]

In letting contracts for the M54 bomb the chief's office directed each procurement district to start negotiations with a minimum of five competent firms for the metal components and subassemblies. Prime contractors were required to subcontract at least 40 percent of the dollar value of their contracts. This provision was aimed at spreading the contracts through certified distressed areas and industries, which still existed in the period of initial war production. The procurement districts awarded these contracts to firms with experience in manufacturing such items as vacuum cleaners, oil filters, and household appliances. While this commercial background was valuable, it was inevitable that problems should arise in the manufacture of new items. The most serious difficulty was fitting the nose and tail to the hexagonal bomb body. The contractors found it hard to obtain the services of qualified tool makers, engineers, and plant inspectors.[6]

[4] (1) Memo, C Ind Svc, OC CWS, for A. H. Browning, SOS, 26 Mar 42, sub: The 4-lb Incendiary Bomb. (2) Memo, ExO Contl Div, OC CWS, for C CWS, 30 Nov 42, sub: Chronology of Events on Requirements of 4-lb Incendiary Bomb. Both CWS 314.7 Incendiary File. (3) Advance Weekly Rpt CWS, No. 33, to Statistics Br, OUSW, 24 Dec 41. CWS 319.1/70.

[5] (1) Memo, Lt Col Charles E. Loucks, ExO to C CWS, for Brig Gen H. K. Rutherford, OUSW, 26 Sep 41, sub: Outline of General Plan Incidental to the Procurement of Incendiary Bombs. (2) Memo, ExO Contl Div, OC CWS, for C CWS, 30 Nov 42, sub: Chronology of Events in Requirements of 4-lb Incendiary Bomb. Both in CWS 314.7 Incendiary File.

[6] (1) History of the Chicago CWPD, 1 July 1940 through 31 December 1944, p. 70. (2) Memo for District Executives, Boston, *et al.,* 11 Oct 41, sub: General Plan for Procurement of Incendiary Bombs. Chicago CWPD 471.6 Bombs 1941. (3) Memo, C Ind Svc, OC CWS, for USW, 24 Dec 41, sub: Report of Accomplishments, Pending Difficulties in Connection with Procurement and Production Activities of CWS. CWS 400.12/106–139. (4) Interv, Hist Off with Col W. P. F. Brawner, 18 Mar 57. Colonel Brawner was Chief, Production Division, San Francisco CWPD, and later Executive Officer, Industrial Division, OC CWS. (5) Brophy and Fisher, *Organizing for War,* ch. VII.

These production and manpower experiences foreshadowed the more pronounced snarls of the later war period both in private industry and in government installations.

The CWS awarded separate contracts for the final assembly and loading of the bomb. The service aimed at confining this type of contract to peacetime manufacturers of fireworks, powder, and explosives. This objective was not always possible, and CWS loading contractors included a wallpaper manufacturer in Chicago and a stove manufacturer on the west coast.

The loading contracts required the government to furnish all items including various fire ingredients such as barium nitrate, grained and flaked aluminum, black powder, and thermite.[7] The need for these and other chemicals in manufacturing incendiary bombs led to unprecedented demands on the chemical industry. For example, before the war only about four hundred tons of barium nitrate per year were manufactured in the United States; the incendiary bomb program required over twice that amount each month. Again, the one producer of thermite in the country turned out about fifty tons a month; the CWS needs rose to over two thousand tons per month. To supply the additional chemicals a number of new plants had to be constructed for the manufacture of barium nitrate and grained aluminum. The facilities of the ceramic industry, which were found to be lying idle because of WPB restrictions, were adapted to the manufacture of thermite.[8]

Immediately after the Pearl Harbor attack, the Under Secretary of War directed the Chief of the Chemical Warfare Service to "take all measures necessary to expedite so far as possible the delivery of incendiary bombs." [9] In January 1942 the OC CWS, after hearing from the War Production Board that magnesium would be available by May or June, notified each of five procurement district offices to arrange for the purchase of components of the M50 bomb.[10] The district offices began immediately to negotiate contracts for components and for casting magnesium bomb bodies.

[7] (1) Memo, C Ind Svc, OC CWS, for Executives, Boston, New York, Pittsburgh, Chicago, and San Francisco Districts, 11 Oct 41, sub: General Plan for Procurement of Incendiary Bombs. Chicago CWPD 471.6. (2) Ltr, C Ind Svc, OC CWS, to USW, 15 Oct 41, sub: General Plan for Procurement of Incendiary Bombs. CWS 471.6/48.

[8] (1) History of the New York CWPD, vol. 1, p. 169. (2) G. H. McIntyre, "Ferro's War Story," *Armed Forces Chemical Journal,* II (October 1947), 12–15.

[9] The quotation appears in Memo, C Ind Svc, OC CWS, for ExO Chicago CWPD, 11 Dec 41. Chicago CWPD 471.6 Bombs 1941.

[10] Ltr, C CWS to CG SOS, 4 Mar 42, sub: Status of Procurement Program for 4-lb Incendiary Bomb. CWS 471.6/29.

The Magnesium Bomb

Magnesium was one of the most critical of wartime metals. In the emergency period the sole producer of the metal in this country was the Dow Chemical Co., which in 1939 turned out a peak peacetime quantity of 6,700,000 pounds.[11] Concern over the need for far greater amounts of magnesium for war needs led to a government loan to the Permanente Metals Corp., organized by Henry J. Kaiser, to build a new plant at Permanente, Calif. in 1941. About the same time the Defense Plant Corp. (DPC) initiated construction of other magnesium plants. By 1943 the DPC had built 13 new plants, which were operated under private contract for the government.[12] For three consecutive years in World War II the CWS took more than one third of all the magnesium produced in the United States for the magnesium bomb program.[13] Total CWS procurement of the metal from 1942 to 1945 amounted to over 288,000,000 pounds.[14] The service wrote contracts with the individual producers for magnesium alloy used in the manufacture of the incendiary munition.[15]

The magnesium bomb (M50) had a magnesium body and a cast iron nose, the body being molded around the nose. Casting of the bomb body in permanent type molds was a new art which made it possible to produce the bombs in large quantities in a relatively short time, at a reasonable cost, and without undue use of critical raw materials. Neither the Germans nor the Japanese developed the art of casting this type of bomb in molds and throughout the war both nations continued to machine the bomb bodies. American manufacturers at first developed their own individual manufacturing techniques, but eventually, with the co-operation of the CWS, they set up a steering committee to exchange information.[16]

Among the very successful CWS contractors on this vital work were the International Silver Co. of Meriden, Conn; L. E. Mason Co. of Hyde Park, Mass.; Dow Chemical Co. of Midland, Mich.; the Permanente

[11] Statement of Hans A. Klagsbrunn, Executive Vice President, Defense Plant Corporation, and Deputy Director, Surplus Property, Reconstruction Finance Corporation, 27 Feb 45, Hearings Before Senate Small Business Committee on Aluminum and Magnesium, p. 1.

[12] See Hans A. Klagsbrunn, "Wartime Aluminum and Magnesium Production," *Industrial and Engineering Chemistry*, vol. 37 (July 1945), 608–17.

[13] H. B. Comstock, *Magnesium*, Reprint from Bulletin 556, Bureau of Mines, 1955, p. 6.

[14] Consolidated Chemical Commodity Report, 16 Oct 51, p. 97.

[15] The alloy consisted of approximately 95 percent magnesium and 5 percent of alum, zinc, and manganese.

[16] Ltr, Lt Col A. C. Hamilton to Hist Off, 11 Sep 57. Colonel Hamilton supervised the incendiary bomb program in the Boston CWPD in World War II.

Metals Corp. of Permanente, Calif.; the American Radiator and Standard Sanitary Corp. of Richmond, Calif.; and the Austin Bridge Co. of Dallas, Tex. In May 1942 the first M50's came off the production line in the New York procurement district.[17] A problem that arose in the manufacture of the bomb body was its tendency to oxidize or "bloom." The oxidation was caused by flux left on the body after the casting operation. The flux was a magnesium chloride compound used on the surface of the molten metal to prevent fires. When a worker dipped his ladle into the melting pot he often picked up some of the flux with the magnesium alloy. Although workers were instructed to push away as much of the flux as possible, they could not entirely eliminate it. In order to remove the substance and thus prevent the oxidation of the bomb, the bodies were pickled after casting. The pickling was generally performed by contractors in the pickling business.[18] In the fall of 1942 the Dow Chemical Co. conducted a study of "bloomed" bombs and concluded that "blooming" was harmful only when it was so pronounced as to prevent the bombs from being tied in bundles, that a wire brush could be used to good effect to eradicate the "bloom," and that as a preventative bomb bodies should be filled as soon as possible after casting and packed in airtight shipping cases.[19]

Another complication in the manufacture of the bomb was the formation of black deposits on the body during casting. It was found that bodies with such deposits would cause fires if rubbed against a metallic substance. By mid-1944 a million and a half of such bombs were segregated and shipped to Pine Bluff Arsenal for storage. A study conducted by representatives of the CWS and the bomb manufacturers disclosed that the deposits were caused by lack of sufficient sulphur dioxide to keep air out of the mold. After considerable experimentation researchers found that the deposit could be prevented to a large degree by regulating the casting temperature, using more sulphur dioxide, cleaning the mold frequently, and taking care to eliminate flux.[20]

A series of explosions in bomb loading plants plagued the CWS in the spring of 1942. Over a 6-week period in March and April four explo-

[17] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 9.

[18] The bombs were dropped into a stainless steel tank containing a pickling solution. This tank was suspended in another tank in which cold water circulated.

[19] (1) Ltr, Maj J. C. Thompson, Plant Representative, to C CWS, 30 Nov 42, sub: "Blooming" of Magnesium Bomb Bodies. Chicago CWPD 471.6 Bombs 1942. (2) J. E. Gilbert, Development of 4-lb Incendiary Bomb AN–M50A2. TDMR 1224, 4 Mar 46.

[20] (1) History of Chicago CWPD, 1 Jul 40 through 31 Dec 44, p. 74. (2) History of Boston CWPD, vol. 11, pp. 22–25. (3) C. E. Miller, Desensitization of "Black Deposits" on M50 Bomb Bodies. TCIR 143, 17 Jun 44.

sions occurred which resulted in eight fatalities. The CWS was so concerned that it shut down the loading plants for several weeks pending an investigation and study by representatives of the Ordnance Department, the CWS, and the loading contractors.[21]

The general causes of the explosion were plain enough. The CWS had taken over a partially developed bomb from the Ordnance Department and under pressure from the War Department had put it into production without adequate lead time. In doing this the CWS did not insist that loading contractors construct explosive proof buildings and use the best safety procedures in filling the bombs. Actually no one knew exactly what the best procedures were, as is indicated by the fact that the War Department had previously classified incendiaries as pyrotechnics instead of explosives. In fact, one of the explosions had occurred at the loading plant at Huntsville Arsenal.[22]

Although the specific causes of the explosions were not fully resolved, investigators learned enough to realize the need for certain changes. One of these related to the handling of the mix that was loaded into the bombs; the decision was made that it should be handled in small batches—100 to 200 pounds. The second change indicated was the need for better housekeeping to prevent the accumulation of dust, to insure proper ventilation of the building, and to provide for the installation of conductive flooring as a means of preventing static electricity.[23]

Oil Bombs

After the M69 6-pound oil bomb was successfully tested at Jefferson Proving Ground in July 1942,[24] the CWS awarded an experimental con-

[21] (1) Memo, C Ind Svc, OC CWS, for USW, 23 Apr 42, sub: Report of Accomplishments, Pending Difficulties in Connection with Procurement and Production Activities of CWS. CWS 400.12/106–139. (2) Joint Conference Commanding Officers of all Districts, Chiefs Incendiary Plants of all Arsenals, and Chief Inspectors and/or safety officers, and all executives and plant superintendents at 9:30 a.m. May 2, 1942, Room 5127, New War Department Bldg., on Loading Hazards in Incendiary Bomb Loading Plants. Chicago CWPD 471.6 Bombs 1942. Hereafter referred to as Joint Conference on Loading Hazards.

[22] Joint Conference on Loading Hazards. It is nevertheless true that efficient loading contractors who had previous experience in the loading of explosives, such as Federal Laboratories, Saltzburg, Pa., experienced no difficulty. This company's plants were constructed in strict accordance with the "Tables of Distances for Explosive Plants" prescribed by the Commonwealth of Pennsylvania. Interv, Hist Off with C. R. Weinert, Technical Director, Federal Laboratories, 14 Nov 57. Mr. Weinert supervised the World War II loading operations at this plant.

[23] (1) Joint Conference on Loading Hazards. (2) CWS Safety Bulletin No. 1, 6 Mar 42, sub: Safety Requirements for the Loading and Handling of AN–M54 and AN–M54X Incendiary Bombs. CWS 314.7 Incendiary File.

[24] (1) See ch. VIII above. (2) History of New York CWPD, 1 Jul 44 to 14 Aug 45, p. 264.

tract for 52,000 of the bombs to the American Machine Defense Corp., New York City. In the fall, after the AAF had indicated heavy requirements for the bomb, the chief's office directed the procurement districts to award contracts for components and filling of the M69. As in the case of the thermate and magnesium bombs, the contracts were of two general types: (1) those for the bomb casing and its components, and (2) those for loading, assembling, clustering, packing, and marking the bomb. In the manufacture of the bomb casing the most difficult problem encountered was brazing the nose of the bomb body. Specifications called for copper brazing, but since copper brazing equipment was in short supply other metals which melted at lower temperatures were used. For example, a New York district contractor employed brass as a weld while several New England contractors used silver solder.[25] The CWS awarded loading, clustering, packing, and marking contracts to firms in the East, the Midwest, and the Far West. The bombs were also loaded under private contract at the CWS Firelands Plant, Marion, Ohio, and Huntsville Arsenal produced over 4,000,000 M69 bombs, which it assembled into more than 111,000 clusters.[26]

In the summer of 1943 the CWS interrupted the M69 procurement program, terminating all existing contracts. The main reason for this action was dissatisfaction with the quick opening cluster, which had not yet been replaced by the aimable cluster. The design of the bomb itself also needed improvement. Early in 1944 technicians developed and put into production an aimable cluster and in the spring the procurement districts began awarding contracts on an improved M69 bomb. This later phase of the M69 program turned out to be much more satisfactory than the earlier phase. With CWS encouragement the contractors set up an integrating committee, which met at frequent intervals with representatives of the CWS in an effort to solve specific manufacturing problems. These meetings were alternately held at various manufacturing plants, thus enabling the contractors to inspect each other's facilities.[27]

In the summer of 1943, meanwhile, the procurement districts began to let contracts for the production of casings for the M74 10-pound oil bomb.

[25] (1) *Ibid.*, p. 266. (2) History of Boston CWPD, 1940–1944, vol. 12, p. 6.

[26] (1) History of Pittsburgh CWPD, p. 222. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 10. (3) Memo, Dr. L. Wilson Greene for Hist Off, 17 Sep 57. Dr. Greene was a CWS officer at Huntsville Arsenal in World War II.

[27] (1) History of the New York CWPD, 1 Jul 44 to 14 Aug 45, pp. 220–38. (2) History of the Boston CWPD, vol. 12, p. 7. (3) History of Pittsburgh CWPD, pp. 221–23.

But not until the following summer did this program get actively under way. In the manufacture of this bomb, no less than in the M69, difficulties arose. For example, the copper brazing of the bomb presented a problem. It was essential that all components fit correctly before the brazing operation, which was carried out in special electrical furnaces built by the General Electric Co. The CWS had to furnish the contractors with these furnaces and most of the other equipment used in making the bomb. The most serious problem encountered in the bomb body was the fabrication of the nosecup. This cup, which measured 3½ inches in length by 2¾ inches in diameter, with a wall thickness of ⅛ inch, required 17 different operations. Since ordinary steel dies could not stand the strain, carboloy dies were developed.

As with other small incendiary bombs, the M74 was loaded and clustered not only under private contract, but at certain CWS arsenals as well. Rocky Mountain and Huntsville Arsenals loaded, clustered, and packed this bomb.[28] No serious complication arose in filling the M74, but the M142 fuze caused a considerable amount of trouble. The design of this fuze, which was manufactured under private contract at the Ordnance Firelands Plant, Marion, Ohio, was such that visual observation did not reveal whether the fuze was armed. After several accidents caused by explosion of the fuze, the CWS changed contractors. The new contractor, the Ferro Enamel Corp., initiated a number of changes to improve safety and handling procedures, which resulted in satisfactory working conditions and a satisfactory fuze.[29]

Since the M74 bomb was designed to penetrate light structures and to eject its incendiary charge in the most vulnerable interior locations, it was regarded as a prime weapon against Japanese structures. The ASF and the CWS therefore rated the procurement of the M74 bomb among the most urgent wartime programs.[30] By the spring of 1945 AAF requirements for the M74 bomb, in anticipation of the invasion of Japan, reached a scale that called for the CWS to multiply its M74 component facilities by five and its loading lines by better than three. At the same time the AAF stepped

[28] (1) History of RMA, vol. IX, pp. 2773–78. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 9.

[29] Ltr, CO HA to C CWS, 22 Dec 44, sub: Fuze, Bomb, M142, and inds. CWS 471, HA–44.

[30] (1) Ltr, Asst C Ind Div, OC CWS to CG ASF, 27 Oct 44, sub: Request for Authorization to Assign AA–1 Preference Rating in the Amount of $500,000 for Critical Equipment Required for M74 Incendiary Bomb. (2) Memo, Dir Prod Div ASF for C CWS, 27 Oct 44, sub: Request for AA–1 Rating for Critical Equipment Required for M74 Incendiary Bomb Program. Both in Chicago CWPD 471.6 Bombs M74, 1944.

up requirements for the M50 to a point where CWS facilities would have to be more than doubled.[31] The war ended before this expansion could be carried out.

Large Incendiary Bombs

The Ordnance Department furnished the bomb bodies for the M47 (100-pound) and M76 (500-pound) bombs which the CWS filled in its own facilities.[32] Edgewood, Rocky Mountain, and Pine Bluff arsenals filled M47's, while Edgewood, Huntsville, and the CWS Firelands Plant filled M76's.[33]

Large facilities and equipment were needed for filling heavy incendiary bombs. For example, at Pine Bluff a tank farm was set up consisting of eight 20,000-gallon tanks. Four centrifugal pumps were used to pump gasoline from car tanks to these storage tanks to the reactor room. The reactor room, one of the largest buildings at the arsenal, was equipped with four 1,000-gallon reactors to prepare the gel for filling the bombs.[34] Plants of this type were set up to perform operations that had no counterpart in industry. It was inevitable that changes in operations would have to be made on the basis of experience.

Napalm [35]

The manufacture of napalm, the metallic soap used to thicken gasoline to form a fill for incendiary bombs and a fuel for flame throwers,

[31] Report, CWS Procurement Conference held at Boston CWPD, 24–25 Apr 45, p. 24. CWS 314.7 Procurement File.

[32] (1) Ltr, C CWS to C Ord, 11 Apr 42, sub: Procurement of Bombs, Incendiary, Liquid M47 (100-lb) and 1st and 2d Inds. CWS 471.6/251–290. (2) Ltr, C Insp Div OC CWS to C Insp Off RMA, 24 Jun 44, sub: M47 Bombs. CWS 471.6 Edgewood Arsenal (Jan through Jun 44).

[33] (1) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 4. (2) Ltr, Mr. Sebastian Kessler to Hist Off, 11 Dec 57. Mr. Kessler was CWS engineer at the Firelands Plant in World War II. (3) Some M47 bombs were also filled in the theaters. See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[34] Preliminary History of Pine Bluff Arsenal (World War II), sec. VII.

[35] Unless otherwise indicated this section is based on (1) History of the San Francisco CWPD in World War II, pp. 82–83; (2) History of Pittsburgh CWPD, pp. 227–28; (3) History of Chemical Commodity Procurement, 1 Aug 44–13 Nov 45, pp. 67–69; (4) Interv, Hist Off with Benjamin M. Redmerski, 10 Jun 58. Redmerski was an officer in charge of production of napalm in the NYCWPD throughout World War II; (5) Ltr, Redmerski to Hist Off, 10 Jul 58; (6) Interv, Hist Off with Maj Eugene F. Lennon, Jr, 16 May 58. (7) Baum, Columbia University Chemical Warfare Service Laboratories, pp. 52–59. (8) G. H. McIntyre, "Ferro's War Story," *Armed Forces Chemical Journal,* II, (October 1947), 14–15. (9) K. E. Long, "The Harshaw War Story," *Ibid.,* II, (January 1948), 48–49.

presented unforeseen problems. Prospective contractors did a great deal of development work at their own expense before any procurement contracts were awarded. The CWS required proof of performance by actually testing samples of the material at Edgewood and at the CWS laboratory in New York City and awarded contracts only to those firms that appeared capable of producing. These contractors included Nuodex Products Co., Elizabeth, N.J.; Imperial Paper and Color Corp., Glens Falls, N.J.; Ferro Enamel Corp. and McGean Chemical Corp., both of Cleveland, Ohio, and California Ink Co. and Oronite Chemical Co., both of San Francisco, Calif. These contractors almost invariably believed that the production of napalm would be a relatively simple matter, much like the manufacture of a commercial soap. In this they were mistaken, as experience soon demonstrated. While the same general processes were employed as in the manufacture of other soaps, napalm had to have standard components and low moisture content in all stages of its manufacture.

One of the item's chief components, naphthenic acid, was a by-product of the petroleum refining process. Since oil from Venezuela and Aruba was rich in that particular acid, it was essential that the producers obtain the oil from those sources. Frequently they could do this by direct contact with commercial handlers, but often the CWS had to assist in securing a supply. Because naphthenic acid was also used as a paint drier and because many paints, particularly those of the quick drying variety, were war requirements, the War Production Board found it necessary to allocate naphthenic acid.

A second important component of napalm, coconut fatty acid, was obtained by boiling and pressing the kernel of dried coconut known as copra. This product, which was also used in the manufacture of shortenings and commercial soaps, was imported. Since many of the coconut producing regions were in war zones, it became very difficult to obtain copra during the war.

Next to the difficulty of securing consistently pure components, the chief problem that arose in producing napalm was its required low moisture content. If the moisture content of napalm was too high, it would result in an ineffective and short-lived mix. Various measures were employed to overcome this difficulty, such as reducing the exposure time of the soap to the surrounding humid atmosphere to a minimum, adding a dehydrating agent to the gasoline along with the soap, and air-conditioning the rooms in which the soap was exposed. The manufacturers used various methods to dry granular napalm. The United Wall Paper Co., for ex-

ample, spread it thinly on wallpaper conveyers and passed it through a heated room. Most contractors placed the powdered napalm on shallow trays which were fitted into mobile racks and then pushed into drying ovens.

In May 1943 the chief's office appointed an officer from the Industrial Division to follow the napalm program closely and report progress to the Production Division, ASF.[36] The CWS laboratories at Edgewood and Columbia University, as well as the NDRC laboratory at Stanford University did considerable research aimed at improving the manufacture of napalm. In addition, government contracts along this line were awarded to such firms as Eastman Kodak Co., Ferro Drier and Chemical Co., Harshaw Chemical Co., Shell Development Co., and Standard Oil Development Co. Despite all these efforts the quality of the napalm continued to vary considerably and mixing problems beset the CWS and the using units throughout the war.[37]

Procurement of the 4.2-Inch Mortar[38]

In directing that two battalions of troops be supplied with 4.2-inch mortars, the Chief of Staff in September 1941 revoked an earlier directive of 19 July 1938 which had suspended the manufacture of the mortar.[39] The decision to supply two battalions presented the Chief, CWS, with an immediate problem of procurement. General Porter's office turned to the Chicago procurement district office, because the 4.2-inch mortar had been allocated to the Crane Co. of Chicago under the prewar procurement plan. But by the fall of 1941 that company was working on other war contracts with higher priority and could not undertake the manufacture of the mortar. The Chicago district office therefore secured bids from five other manufacturers, two of whom were awarded contracts—the Bell Machine Co. of Oshkosh, Wis., and the Oakes Products Division of Houdaille-Hershey Co., Decatur, Ill. The Bell Machine Co. concentrated on the manu-

[36] Memo, C Facilities & Inspec Br for Dir, Prod Div, ASF, 22 May 43, sub: Fillers for M47, or M47A1, and M69 Incendiary Bombs. ASF 471.6 Grenade Bombs.

[37] See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[38] Unless otherwise indicated, this section is based on the History of the Chicago CWPD, 1 July 1940 through 31 December 1944, pp. 59–62, 1 January 1945–15 August 1945, pp. 51–52, and interviews with M. A. Bell, manufacturer of the 4.2-inch mortar (4 April 1957) and with the following key officers who were intimately acquainted with the manufacture of the mortar: Col Gilbert C. White (4 April 1957), Lt Col Walter E. Spicer, Jr., (28 April 1955), Lt Col J. S. Entriken (21 June 1956), and Lt Col Robert C. Hinckley (15 October 1956).

[39] Memo, ACofS G–3 for TAG, 5 Sep 41, sub: Chemical Troops, G–3/46556. The 19 July 1938 directive, among others, is referred to in Memo, ACofS, G–4 for AC of SWPD, 28 Mar 40, sub: Lack of Chemical Warfare Weapons and Supplies. G–4/29895–1.

facture of the barrel, while the Oakes Products Division made the carts for the mortar.[40] Other contracts were let for such parts as base plates, recoil springs, and elevating screws.

The Bell Machine Co., a manufacturer of custom-made woodworking machinery in peacetime, undoubtedly did not foresee the tough job it would encounter in rifling the barrel of the mortar. The 4.2-inch barrel was unique in U.S. Army munitions in that it employed ratchet type rifling rather than the simple spiral rifling employed in small arms and in most field pieces. This feature seriously complicated the broaching of the barrel, as the Bell Co. and the CWS inspectors from the Chicago district shortly came to learn.

Early in 1942 a broaching machine arrived at Oshkosh from Edgewood. Some 56 barrels had been rifled on this machine when it was discovered that 4 inches of the rifling toward the muzzle were defective. Little progress could be made in manufacturing the barrel until a suitable broaching machine was obtained. To overcome the difficulty the OC CWS, awarded a contract to the American Broach Co., Ann Arbor, for the design of a new 35-ton hydraulic broach. This broach when put into operation was to prove very satisfactory, but it was not ready for installation at the Bell Machine Co. until June 1943. Meanwhile the manufacture of the barrels had been delayed for more than a year. Only 823 barrels were manufactured in 1942, compared to 2,002 in 1943 and 2,600 in 1944.[41] By October 1944 the Bell plant had a capacity of 800 to 1,000 mortars a month, but the production schedule called for only 200.[42]

While the rifling of the barrel was the most perplexing task encountered in producing the mortar, several other hitches arose. In each instance these difficulties were the outgrowth of efforts to increase the range of the mortar. Base plates and recoil springs broke and elevating screws bent. The CWS laboratories at Edgewood and M.I.T. worked on these problems and, in addition, the service awarded contracts to private manufacturers who were specialists in particular items. For example, it awarded a contract to A. O. Smith Corp. of Milwaukee to improve the welding technique employed in the manufacture of the base plate. This company did an excellent job in working out the necessary preheating, positioning,

[40] Contracts W799-CWS-189 and 190.

[41] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 24.

[42] Ltr, Lt Col C. B. Watkins, IGD, to Actg IG (through CO CCWPD, C CWS, and CG ASF), 26 Oct 44, sub: Special Inspection of CCWPD and Inspection Service, Chicago, Illinois. CWS 333.1.

welding sequence, and heat treatment for a base plate suitable for CWS purposes. The Pullman Standard Car Co. of Hammond, Ind., also worked on the improvement of the base plate. L. A. Young Steel and Wire Co. of Detroit provided the CWS with a greatly improved spring, while Foote Brothers Gear and Machine Co. and the Lindberg Engineering Co., both of Chicago, did much to perfect the elevating screw. By mid-1944 most of the technical problems arising in the manufacture of the mortar had been solved.[43]

In 1943, as indicated above, the CWS began to develop a recoilless 4.2-inch mortar. In September 1944 the service placed an experimental contract with the Budd Wheel Co. of Detroit for the manufacture of 25 of the new recoilless mortars.[44] After receiving these 25 prototype samples the Office of the Chief directed the Chicago procurement district to investigate the possibility of procuring the item on a mass basis. Late in 1944 the Office of the Chief sent the drawings and specifications on the new recoilless mortar to the Chicago procurement district with the view of obtaining a contractor to produce the item on a mass production basis. On examining the drawings and specifications, the Chicago district decided that the most practicable procedure would be to superimpose the contract on the Bell Machine Co. and on 24 January 1945 a letter of intent for 1,000 barrels was issued to that company. The Bell plant had to be retooled for the new mortar, a process which proved very time consuming, and by the war's end Bell had turned out only 100 of the models.[45] Two days after V-J Day 12 of these reached the Pacific theater.[46]

The CWS first conducted proofing of the mortar exclusively at Edgewood Arsenal, but beginning in late 1942 some mortars were also proofed at Huntsville Arsenal. From mid-1943 until the spring of 1944 all mortars were fired for acceptance inspection at Huntsville. The mortars were shipped from the points of manufacture, assembled, and fired. Proofing procedures consisted of firing sand filled shells, using a heavy propellant

[43] (1) T. R. Paulson, Development of the 4.2-inch Chemical Mortar E35R1, 18 Mar 46, TDMR 1202, p. 23. (2) Memo, C Proof Sec, Chemical Mortar Proof-testing Br Camp McCoy to C Insp Office Chicago CWPD, 3 Oct 44, sub: Special Test on Elevating Screws. Chicago CWPD 472.4, Chemical Mortars. (3) Report on 4.2-inch Mortar Base Plate by A. O. Smith Corp. ETF 2182–6.

[44] (1) Ltr, C Insp Off EA to C Insp Div, 6 Sep 44, sub: Mortar, Chemical, 4.2–Inch Recoilless, E34. (2) Memo, C Offense Matl Br for AC Mfg and Proc CWC EA, 6 Oct 44, sub: Status of the 4.2-Inch Recoilless Chemical Mortar. Both in CWS 472.4.

[45] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 24.

[46] CWTC Item 1785, Obsoletion of the Mortar, Chemical, 4.2-Inch Recoilless, M4, and the Shell, 4.2-Inch Recoilless Chemical Mortar, M6, with Cancellation of Related Military Requirements and Development Type Items, 25 Sep 47.

charge. If found satisfactory, the mortars, together with mortar carts, were shipped to the theaters of operation or points in the zone of interior.[47]

Since shipping the mortar parts to Edgewood and Huntsville caused considerable delay, the CWS in the spring of 1944 investigated the possibility of acquiring a proofing site nearer the point of manufacture. After arrangements were made in July 1944 all mortars were proofed at Camp McCoy, Sparta, Wis., until the war was over.[48]

Procurement of the 4.2-Inch Mortar Shell [49]

In the prewar years the CWS procured 4.2-inch shells from Frankford Ordnance Arsenal. While the Ordnance Department could supply the peacetime needs of the CWS, it was in no position in mid-1940 to fill an order for 47,626 E38R2 shells. The Office of the Chief was therefore obliged to obtain these shells through private contract. It directed the commanding officer of the Pittsburgh procurement district to send invitations to bid to four likely contractors for machining, assembling, and packing the shells. The lowest bidder was the H. K. Porter Co. of Pittsburgh, a reputable manufacturer of industrial locomotives, diesel engines, and chemical processing equipment. Under the contract the government agreed to furnish some $77,000 worth of equipment—government-furnished equipment being a common feature of wartime contracts. About the same time that the Porter contract was awarded, other contracts were let to some

[47] (1) TT, CO Chicago CWPD to CO HA, 23 Dec 42. Chicago CWPD 472.4 Chemical Mortars 1942–1943. (2) Ltr, C Insp Div OC CWS to C Insp Off EA, 6 Jul 43, sub: Proofing and Reconditioning of Mortars. CWS 472.4 EA 43. (3) Ltr, C Insp Div OC CWS to C Insp Off HA, 14 Feb 44, sub: Responsibility of Inspection Office—Proofing of 4.2-Inch Chemical Mortars. CWS 472.4 HA 44. (4) History of Chemical Warfare Center, p. 248. (5) History of Huntsville Arsenal, vol. 2, p. 785.

[48] (1) Hinckley interv, 15 Oct 56. (2) History of the Chicago CWPD, 1 Jan 45–15 Aug 45, p. 52.

[49] Unless otherwise indicated this section is based on: (1) History of the Pittsburgh CWPD, pp. 192–207. (2) History of the Chicago CWPD, 1 July 1940 through 31 December 1944, p. 63. (3) History of the Dallas CWPD, February 1942–June 1944, pp. 93–97. (4) History of the Dallas CWPD, 1 July 1944–14 August 1945, p. 35. (5) History of the Boston CWPD, 1940–1944, vol. 8, pp. 1–4. (6) History of San Francisco CWPD in World War II, pp. 76–78. (7) Analysis of Chemical Warfare Service Pricing Record World War II, pp. 59–62. (8) Lt G. E. McCullough, Engineering Test of 4.2-Inch Chemical Mortar Shell Experimental—Manufactured by the Scaife Company. TDMR 348, 11 Feb 42. (9) Ltr, Ch Tech Div OC CWS to A. V. Murray, Scaife Co., 3 Nov 44, with enclosure History of the Development of the Fabricated 4.2-Inch Chemical Mortar Shell, 31 Oct 44. SPCVF-141 Scaife Co., CWS 314.7 Procurement File. (10) Interv, Hist Off with Paul A. Varley, 6 Nov 56. Varley was the CWS officer in charge of the mortar shell program in the Pittsburgh CWPD in World War II. (11) Interv, Hist Off with C. E. Johnson, Vice President for Engineering, Scaife Co., 13 Nov 57. Johnson worked on mortar shell engineering in World War II.

half dozen prime contractors for such components of the shell as the burster tube well, the vane, the cartridge container, and the striker nut. A contract for forging shell bodies was awarded to the Pennsylvania Forge Co.[50]

In October 1941 the War Department authorized procurement of 160,879 more E38R2 shells; later this authorization was changed to 143,230 M2 shells and 33,584 M3 shells. The OC, CWS, directed the Pittsburgh district to procure these additional shells, whereupon the contracting officer of that district sent invitations to bid to six prospective contractors. The successful bidders were the Lempco Products Co. of Cleveland, a producer of industrial machine tools, grinders, and equipment used in the automotive industry; the Hydril Corp., Rochester, Pa., a manufacturer of oil field supplies and equipment; and the H. K. Porter Co. which was already working on the shell.

With the vast increase in requirements for 4.2-inch mortar ammunition, the CWS began to investigate the possibility of manufacturing the shell more quickly and economically than by the forging process. In the 1930's the Ordnance Department in an effort to make a less expensive shell had experimented with one fabricated from seamless steel tubing, but this experiment had not proved successful.[51] In the summer of 1941 the matter was brought up in a discussion between Maj. J. L. Rose of the Office of the Chief and R. F. Cecil, vice president of the Scaife Co., Oakmont, Pa. The Scaife Co., a producer of boilers, pressure vessels, and commercial and domestic hot water tanks, specialized in the field of steel tubing. Cecil suggested to Rose the possibility of fabricating the shell from commercial hot rolled tubing and of brazing both base and nose adapter to the casing of the shell.[52] The practice at the time was to weld the base and adapter to the casing and this had not proved satisfactory. After the CWS had shown keen interest in Cecil's suggestions, the Scaife Co., at its own expense, worked on these developments both in its own laboratories and at the Mellon Institute of Industrial Research, Pittsburgh, Pa., where it sponsored a research fellowship. On 22 December 1941 the company was able to deliver ten fabricated shells with bases and adapters brazed to the casings to Edgewood Arsenal, where the shells were tested and proved

[50] (1) History of the Pittsburgh CWPD, pp. 192–93. (2) Varley interv, 6 Nov 56.

[51] Charles T. Mitchell, Outline of 4.2-Inch Chemical Mortar Development, p. 66. ETF 218–26, 22 Feb 45.

[52] An adapter is "a metal lining put into the nose or base of a shell to make it fit the fuze." TM 20–205, 18 Jan 44.

satisfactory.[53] The CWS then awarded the Scaife Co. the first of several wartime production contracts. The company's findings were made available to other mortar shell manufacturers, so that the bulk of 4.2-inch shells produced in World War II were of the fabricated variety. In the fabricated shell the requirement for steel was 20 pounds to the shell as compared to 50 pounds in the forged shell.

By the spring of 1942 requirements for the shell had reached a point where the CWS felt obliged to seek additional contractors, and the service awarded 4 additional prime contracts at that time. Two of the new contractors, Erie Basin Metal Products, Inc., and the David Bradley Manufacturing Division of Sears Roebuck and Co., were located in the Chicago Chemical Procurement District. The other 2, the Guiberson Co. and Hardwicke Etter Co., were in the Dallas procurement district. In 1943 another prime contractor was added, the Day and Night Manufacturing Co. in the San Francisco district. Early in 1945 prime contracts were awarded 5 more manufacturers, 3 in the Boston procurement district and 2 in the Dallas procurement district. But the war came to an end before any of these 5 got into production.

In order to exchange information on the 4.2-inch shell program, a Shell Manufacturers Co-ordinating Committee was established in 1942. This committee, whose chairman was Mr. Cecil of the Scaife Co., held monthly meetings, at which one representative of each manufacturer in the United States was present. In attendance also, but not as active committee members, were experienced officers and civilians from the CWS.[54]

The CWS estimated requirements for the shell on the basis of a continually growing theater demand and, of course, passed on the requirements to Headquarters, ASF, to be incorporated into the Army Supply Program. On 1 October 1944 the ASF reduced the Army Supply Program figure for 4.2-inch shells from 5,645,306 to 4,007,000 without stating the reasons. After the CWS protested this action, Headquarters, ASF, reversed its decision and on 13 November approved the original figure of 5,645,306. The CWS had meanwhile been retarded over a six-week period in efforts to secure steel for its 1945 production, a procedure that required considerable

[53] (1) Lt G. E. McCullough, Engineering Test of 4.2-Inch Chemical Mortar Shell Experimental—Manufactured by the Scaife Company. TDMR 348, 11 Feb 42. (2) Charles T. Mitchell, Outline of 4.2-inch Chemical Mortar Development, p. 66. ETF 218-26, 22 Feb 45.

[54] Ltr, Asst C Ind Div, OC CWS, to CG's of all arsenals and CO's of all CWPD's, 28 Dec 42, sub: 4.2 Chemical Mortar Shell Manufacturing Committee Meetings. Chicago CWPD 471.3.

lead time. Early in 1945 reports from the theaters of operations indicated that the 4.2-inch shell was in such short supply that commanders had resorted to rationing. This development was probably an outcome of the ASF action of 1 October in cutting back shell requirements; at least the CWS felt that it was.[55]

The Shell Fuze

When the procurement of the shell was allocated to the Pittsburgh district in 1940 a contract was awarded to the Westinghouse Airbrake Co. for assembling the metal components of the fuze and to the Acme Die and Machine Co. for loading the fuze. Later, contractors for the assembly of the metal components were Casco Products Co., Bridgeport, Conn.; Atlas Ansonia, North Haven, Conn.; Heckethorne Manufacturing Co., Littleton, Colo.; Milwaukee Stamping Co., Milwaukee, Wis.; Louis S. Dow, Minneapolis, Minn.; and Simset Manufacturing Co., Oakland, Calif. In addition to the Acme Die and Machine Co., the following contractors and arsenals loaded fuzes during the war: Atlas Ansonia; William M. Fencil Manufacturing Co., Huntley, Ill.; National Fireworks, Inc., West Hanover, Mass.; Pine Bluff Arsenal, Arkansas Ordnance Plant, Little Rock, Ark.; and Picatinny Ordnance Arsenal, Dover, N.J. Loaded fuzes and empty shells were shipped to CWS arsenals (Edgewood, Pine Bluff, and Huntsville) for loading with chemicals and to Ordnance plants or contractors for loading with high explosives. Ordnance plants loading HE shells were Kansas Ordnance Plant, Parsons, Kans.; Louisiana Ordnance Plant, Minden, La.; and Picatinny Arsenal, Dover, N.J. Ordnance contractors loading the shell were National Fireworks Inc., and National Munitions, Eldred, Pa.[56]

During the war there were a number of instances when rounds of ammunition exploded prematurely either in the barrel of the 4.2-inch mortar or immediately after leaving the muzzle. This matter was given considerable publicity after the war when the Special Senate Committee Investigating the National Defense Program was holding hearings on Erie Basin

[55] Memo, C Field Requirements Div OC CWS for Col Elliott (Deputy Chief CWS), 3 Mar 45, SPCWD. (2) Min, Mtg, Requirements Planning Committee, OC CWS, 28 Feb 45. (3) Min, Mtg, Requirements Planning Committee, OC CWS, 6 Nov 44. All in CWS 314.7 Requirements File.

[56] Report on Malfunctions of the 4.2 Chemical Mortar Ammunition, Their Cause, Effect, and the Measures Taken to Correct the Deficiencies, 12 Aug 46. A report prepared by the C CWS, for USW, Appendix 559. Hereafter cited as Report on Malfunctions.

4.2-INCH WP CHEMICAL MORTAR SHELLS *on an assembly line, Pine Bluff Arsenal, Arkansas.*

Metal Products, Inc.[57] The committee then requested the Chief, CWS, to furnish accurate figures on how many were killed and wounded by these premature explosions or bursts.[58]

The CWS reported that during the war there were sixty-three premature explosions in the zone of interior and the theaters of operation. These explosions brought death to thirty-eight American soldiers and injury to 127. After each explosion the lot of ammunition was impounded and a thorough investigation made. Some commanding officers in the field felt it tactically urgent to utilize the ammunition even after it had been declared unsafe.[59] In every instance, it was found that faulty fuzes were a factor in premature bursts.[60] Various malpractices in fuze manufacture, in some cases the result of lack of experience, were discovered. Among these were failure to put steel safety balls in the fuzes, the use of inaccurate and uncontrolled methods of loading the fuze, the stacking of detonators

[57] See below, pp. 361–67.

[58] *Investigation of the National Defense Program, Hearings before a Special Committee Investigating the National Defense Program,* U.S. Senate, 79th Cong. 2d sess., pursuant to S.R. 55, 79th Cong., extending S.R. 71, 77th Cong. (Washington, 1947), p. 19071. Hereafter cited as *Hearings.*

[59] See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[60] Other factors that had a possible bearing on premature bursts were poor packaging and storage of chemical shells. See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

into position rather than cementing the detonator cap.[61] One manufacturer, National Fireworks, Inc., was singled out has having had a disproportionate number of detonator rejects and faulty plant practices. The CWS conceded that had inspectors been on the alert these conditions would not have existed.[62]

The CWS required its inspectors to examine all fuzes before they were released to the loading plants by the assemblers. After receiving complaints from the field on the malfunctioning of 4.2-inch mortar ammunition, the service reviewed all inspection practices. The Inspection Division, OC CWS, called several conferences, the most noteworthy being held in Milwaukee on 5 January 1945. The purpose behind this conference was restudy of all phases of fuze manufacture and review of all authorized waivers and changes to insure that they did not compromise proper functioning of the fuze. In attendance at the conference were representatives of the CWS and all contractors assembling and loading the fuze. The day after the conference the group visited the Fencil plant at Huntley, Ill., to review at first hand problems associated with the assembling and loading of the fuze.[63] This plant had an excellent record in producing safe fuzes.

The Fencil plant's success was the result of the extreme precautions its owner took both in constructing the plant and in carrying out loading operations. William M. Fencil, who headed the company, had been trained as a chemical engineer and in peacetime had been a manufacturer of gaskets. He wanted to engage in war work and after approaching the office of the CWS Chicago procurement district in mid-1942 he learned of the search for suitable contractors to assemble and load the fuze. Fencil's educational background and business experience impressed the CWS procurement office, where he was given favorable consideration. Before undertaking a contract Fencil made a thorough study of Ordnance manuals on ammunition and made a tour of a well run ammunition loading plant. When he built his own plant at Huntley, Fencil took pains to see that all safety features were incorporated into the design. He was equally cautious in carrying out loading operations. Convinced that the primary need was for

[61] The term "stacking the detonators" referred to the practice of holding the detonator in place by means of metal prongs raised from the surface of the slider. These prongs sometimes abraded the delicate mechanism and caused a rough surface subject to corrosion. Cemented detonators, on the other hand, left the slider smooth and the cement coating itself was a protection against corrosion.

[62] Report of Malfunctions, Abstract preceding Table of Contents.

[63] Minutes of meeting between representatives of U.S. Army and representatives of industry on the 4.2-inch mortar fuze, held at the Milwaukee Stamping Co., West Allis, Wis., on the 5th day of January 1945, at 0900. 314.7 Procurement File.

safety rather than mass production, he hired a great many inspectors to insure that every fuze was properly loaded. He set up a procedure whereby after 100 fuzes had been loaded operations were interrupted to ascertain if one or more components were left over. If such was the case the entire 100 were disassembled and reworked. While this procedure tended to slow up production, it insured the loading of safe fuzes.[64]

In contrast to the practice at CWS arsenals and privately operated plants, there was no CWS inspection of fuzes loaded at Ordnance plants. Since the Ordnance Department was the biggest and presumably the most competent munitions loader in the United States, the CWS felt that it did not need to have inspectors at those plants. This arrangement was discussed and agreed upon by the CWS and the Ordnance Department.[65]

Criminal Involvement of Mortar Shell Contractors

During World War II CWS contractors became involved on two separate occasions in criminal activities that led to court trials and convictions.[66] While both these trials attracted considerable publicity, the second elicited far more attention than the first for it involved a prominent United States Representative from Kentucky, Andrew Jackson May, who was Chairman of the House Committee on Military Affairs. May, together with Murray Garsson and his brother Henry M. Garsson, were tried and convicted in a federal court in the District of Columbia for conspiring to defraud the government. In July 1947 they were each sentenced to serve from eight months to three years in a federal penitentiary.[67]

Just a year before sentence was passed the affairs of Congressman May and the Garssons were publicly aired at hearings before the Special Committee of the U.S. Senate Investigating the National Defense Program.[68] In July 1946 this committee took testimony relative to government

[64] (1) History of Chicago CWPD, 1 Jan 45–15 Aug 45, p. 54. (2) Interv, Hist Off with William M. Fencil, 14 Mar 58. (3) Hinckley interv, 15 Oct 56.

[65] Report on Malfunctions, p. 74.

[66] The first of these trials involved underloading of incendiary bombs and grenades by the Antonelli Fireworks Co. of Spencerport, N.Y. On 10 June 1944 a Federal jury in Rochester, N.Y. found the president, two superintendents, and a foreman of this company guilty of conspiracy to defraud the government. The indictment had also charged the defendants with sabotage, but the jury after deliberating for thirteen hours failed to find them guilty on that count. See Report of Antonelli Fireworks Co., Indictment and Trial for Criminal Activities in Connection with CWS Contracts, compiled by the CWS legal adviser. CWS 314.7 Antonelli Case File.

[67] Sentence was pronounced by Judge Henry A. Schweinhaut. See *World Almanac and Book of Facts for 1948*, p. 760.

[68] *Hearings*, pts. 34 and 35.

contracts with two corporations in which the Garsson brothers served as officers, Erie Basin Metal Products, Inc., and Batavia Metal Products, Inc. The government agency party to the contracts was the Ordnance Department in some instances and the Chemical Warfare Service in others. A great deal of the testimony centered around the contacts between several key officers of the Chemical Warfare Service and the Garsson brothers. It was disclosed that in the summer of 1941 Henry Garsson went to the office of Col. Paul X. English, then executive officer to the Chief, CWS, to inquire about the possibility of obtaining a war contract. Garsson said he was representing the Segal Lock and Hardware Co., Brooklyn, N.Y., which was setting up a subsidiary, the Erie Basin Metal Products, Inc., for the purpose of doing war work. This company, Garsson stated, was particularly interested in a contract to manufacture 4.2-inch mortar shells.[69] On 7 October 1941 Henry Garsson wrote a letter to the Chemical Warfare Service in which he made a bid on the mortar shell. He stated that Erie Basin Metal Products, Inc., "organized under the laws of state of New York," was an affiliate of the Norwalk Lock Co. and a subsidiary of the Segal Lock and Hardware Co. One week later, Colonel English thereupon addressed a letter to Henry Garsson, Erie Basin Metal Products, Inc., 395 Broadway, New York, N.Y., pointing out that there would not be the immediate demand for the 4.2-inch shell that had been anticipated and that the CWS therefore would not be able to award a contract.[70] It was brought out at the hearings that at that time the Erie Basin Metal Products company had not come into existence, that it was not incorporated in the state of New York until 29 January 1942, and that it was not at any time an affiliate of the Norwalk Lock Co. or a subsidiary of the Segal Lock and Hardware Co.[71]

Actually Henry Garsson was employed as a consultant engineer by the Segal Co. and according to Louis Segal, president of that company, he performed very satisfactorily. Garsson had suggested to Segal that the Erie Basin company be set up as a subsidiary of the Segal Lock and Hardware but the suggestion was never implemented.[72] Apparently while awaiting word from Mr. Segal, Henry Garsson on 25 January 1942 met Allen B.

[69] *Hearings*, pt. 34, p. 17678.

[70] *Hearings*, pt. 35, Exhibit 1939.

[71] (1) *Hearings*, pt. 34, Certificate 2476B, State of New York, County of New York, 29 Jan 42, being Exhibit 1756. (2) *Hearings*, pt. 34, p. 17760, testimony of Louis Segal, President of Segal Lock and Hardware Co.

[72] *Ibid.*, pp. 17781–87.

Gellman in the Washington office of Congressman Sabath of Illinois. Gellman's family and the family of Joseph T. Weiss owned several Illinois corporations, including the Illinois Watch Case Co., which made watch cases and metallic novelties, and the United States Wind Engine and Pump Co., which made farm implements and railroad supplies. When Gellman heard of Garsson's interest in the 4.2-inch mortar shell, his curiosity was aroused because he recognized that this was a mass production item which his plants could make.[73] Gellman agreed to assist Henry Garsson and his brother financially and this agreement flowered into an amazingly complicated financial structure, in the manipulations of which Congressman May became entangled. These manipulations were the chief target of Senate investigators, who contended that their purpose was the realization of excessive war profits.

Five days after Gellman met Garsson and one day after Erie Basin Metal Products, Inc., was certified as a New York corporation, Colonel English, now Chief, Industrial Service, OC CWS, as CWS contracting officer, issued a letter of intent to the new company at 75 West Street, New York, N.Y.[74] This letter was an order for 15,000 4.2-inch chemical mortar shell bodies and 15,000 chemical mortar shell fuzes, "the shell bodies f.o.b. common carrier, Brooklyn, N.Y., or Elgin, Ill., the fuzes, f.o.b. common carrier, point of loading and assembly." [75] A provision to manufacture an item at either of two locations was seldom if ever included in government contracts. The provision for the manufacture of fuzes was deleted as of 27 April 1942.[76]

At the time Colonel English issued the letter of intent to Erie Basin Metal Products, Inc., he forwarded a directive to the New York procurement district, and apparently to the Chicago district also, to begin preparation of a formal contract. On 23 February 1942 the commanding officer of the New York district sent a confidential memorandum to the Chief, CWS, stating that Henry Garsson's statements regarding the status of Erie Basin Metal Products, Inc., were contradicted by Louis Segal. A copy of this memorandum was sent to the commanding officer of the Chicago Chemical Warfare Procurement District.[77]

[73] *Hearings*, pt. 35, p. 18809.

[74] A letter of intent served as a contract until a more formal contract was written.

[75] *Hearings*, pt. 34, Exhibit 1757.

[76] (1) Interv, Hist Off with Lt Col Robert M. Estes, former Chief, Purchase Policies Division, OC CWS, 18 May 52. (2) Personal Statement of Lt Col Robert M. Estes on Erie Basin Metal Products, Inc., p. 1. This 33-page statement, which was compiled during and after World War II was turned over to the Chemical Corps Historical Office in 1952. CWS 314.7 Procurement File.

[77] *Hearings*, pt. 34, Exhibit A-17, p. 18267.

Why did neither the chief's office nor the Chicago Procurement District office act on this memorandum casting doubt on Henry Garsson's trustworthiness? To this question the Senate investigators were most anxious to obtain an answer. Brig. Gen. Paul X. English testified that he did not see the memorandum until it was brought to his attention in the latter part of 1943 in connection with the renegotiation of the contract. He stated that if he had seen it in February 1942 he would not have gone through with the contract, at least not before thoroughly investigating Mr. Segal's statement.[78] The commanding officer of the Chicago district recalled having received the memorandum but could not recall whether it was before or after he signed the contract.[79] But regardless of the memorandum, he declared, he would have signed the contract because the letter of intent and General English's signature on the contract itself, dated 1 March 1942, gave him no alternative.[80] To this statement General English took vigorous exception, saying that under no conditions was a commanding officer supposed to "go blindly into" a contract.[81] The 1 March contract was the first of a number which the CWS awarded to two companies in which the Garssons obtained an interest—Erie Basin Metal Products, Inc., and the Batavia Metal Products company.

Why wasn't the memorandum from the commanding officer of the New York Procurement District brought to General English's attention in February 1942? No definite answer to that question was forthcoming at the hearings. But the committee left little doubt as to whom it thought was responsible for the failure. It strongly intimated that a civilian lawyer in the Office of the Chief, CWS, who was closely associated with Congressman May and the Garssons, was the culprit. Toward the end of the hearings several members of the committee accused this lawyer, whose legal career before coming into the Chemical Warfare Service had been under a cloud, of perjury and of purloining documents and records. The chairman of the committee said he hoped the Department of Justice would look into the man's record.[82] If the Department of Justice followed up the suggestion, it apparently did not feel there was sufficient evidence for conviction because the individual was not prosecuted.

He was the only person in the CWS whose motives the committee questioned. Several committee members did imply, and with seemingly

[78] (1) *Ibid.*, p. 17686. (2) Interv, Hist Off with Brig Gen P. X. English, 26 Oct 56.
[79] *Hearings*, pt. 34, p. 17648.
[80] *Ibid.*, pp. 17651, 17684.
[81] *Ibid.*, p. 17683.
[82] *Hearings*, pt. 35, pp. 18934–36.

good reason, that the judgment of several CWS officers left something to be desired. On the other hand, the committee hearings brought to light that other CWS officers used extremely good judgment and were most solicitous for the welfare of the government in their dealings with companies controlled by the Garsson interests. Particularly noteworthy was the role played by the chief of the Purchase Policies Branch, Colonel Estes.[83] Estes' attention was drawn to the Erie Basin and Batavia Metal companies by the unusual high prices in the contracts. He had made some headway in reducing these prices, but in December 1944 they were still so high that Estes advised the Renegotiation Division, ASF, to request a Bureau of Internal Revenue audit on the Garsson brothers.[84] On 2 January 1945 the Renegotiation Division replied, stating that Estes' proposal for an audit was considered impractical. Then on 8 May, Estes personally conferred with the Chicago Bureau of Internal Revenue District Field Office, where he learned that an audit on the Garssons was already under way. Early in the summer of 1945 the ASF reversed its previous decision and concurred in requesting an audit from the Bureau of Internal Revenue.[85]

In January 1945, meanwhile, Estes called the attention of a CWS procurement conference to the terms of the Erie Basin contract, terms which enabled the contractor "to pay higher salaries, buy $500,000 worth of equipment from an affiliate, and within half a year write off half of his shell production facilities, in addition to paying $250,000 rent to another affiliate."[86] These remarks attracted the attention of Brig. Gen. Charles E. Loucks, Chief, Industrial Division, OC CWS, who had been making some observations on his own on the "fantastic" prices in the Garsson contracts.[87] General Loucks deputized Colonel Sanson of his staff to review those contracts for the purpose of revising them downward, and early in 1945 this was done.[88]

On V-J Day, 14 August 1945, Colonel Estes advised the Legal Branch, OC CWS, through the Assistant Chief, CWS, for Materiel, General

[83] *Hearings*, pt. 34, pp. 18075, 18100–102, 18107–109.

[84] Ltr, C Purchase Policies Br OC CWS to C Renegotiation Div, ASF, attn: Lt Col W. W. Watts, 8 Dec 44, sub: 1943 Renegotiation of Erie Metal Products Inc. and Illinois Watch Case Co., Inc., Elgin, Ill. Copy in CWS 314.7 Garsson Case File.

[85] Ltrs, R. M. Estes to Hist Off, 30 Jan 52 and 4 Mar 52, and Ltr, Brig Gen Charles E. Loucks, Acting Chief Chemical Officer to Hist Off, 21 Mar 52, commenting on Estes 4 Mar 52 ltr.

[86] Report of CWS Procurement Conference held at Pittsburgh, Pa., 8 Jan 45. CWS 314.7 Procurement File.

[87] Ltr, Brig Gen Charles E. Loucks to Hist Off, 21 Mar 52.

[88] *Hearings*, pt. 34, pp. 17743–54.

Ditto, that no termination payments should be made to the Erie Basin Metal Products companies until the full extent of the liabilities of those companies to the government had been determined.[89] A week later Estes addressed a second memorandum directly to the Renegotiation Division, ASF, in which he again urged the withholding of invoice and termination claims to the Erie Basin company in order to protect the interests of government in recovering excessive profits.[90] Colonel Estes' letter was followed by positive action on the part of the Renegotiation Division, ASF, which suggested to the Office of the Under Secretary of War that a withholding order be issued against Erie Basin. The Under Secretary's office issued such an order on 6 September 1945.[91]

The Under Secretary's order to withhold funds brought vigorous reaction from the Garssons and their associates. Before it was issued the civilian lawyer in the OC CWS referred to above, drafted a letter for the Commanding General, ASF, which the Assistant Chief, CWS, for Materiel signed, criticizing the position the Purchase Policies Branch had taken.[92] Congressman May bombarded Under Secretary Patterson's office with phone calls. Patterson turned the problem over to Kenneth C. Royall, a special assistant. On the basis of a survey the Under Secretary issued a directive on 15 September modifying the freeze order of 6 September.[93]

No mention whatever was made in the withholding orders of any company other than the Erie Basin Metal company. Mr. Royall, after he had become Under Secretary of War, said he had never even heard of the Batavia Metals company until May 1946 when he was informed of the following developments.[94] On 13 September 1945 the Settlement Advisory Board of the Chemical Warfare Procurement District, acting on what they considered reliable data, made a partial payment to the Batavia Metal Products company of $3,846,700 of which amount $3,231,649.60 went to liquidate the outstanding balance of the government's advance payment account and the remainder was paid to the contractor. Subsequently, an audit of this company's account disclosed some rather unusual accounting

[89] Ltr, C Purchase Policies Br OC CWS to C Legal Br, thru: AC CWS for Mat'l, 14 Aug 45, sub: Renegotiation and Termination Settlements with Erie Basin Metal Products, Inc. Copy in CWS 314.7 Garsson Case File.

[90] Memo, C Purchase Policies Br OC CWS for Dir Renegotiation Div, ASF, 23 Aug 45, sub: Withholding Payments of Invoices and Termination Claims to Protect Government Interest in Recovery of Excessive Profits. *Hearings*, Exhibit 1860.

[91] *Hearings*, pt. 34, Exhibit 1861, p. 18099.

[92] *Ibid.*, Exhibit 1890.

[93] *Ibid.*, Exhibit 1863.

[94] *Ibid.*, p. 18176.

practices and it was concluded that the Batavia company's invoices to the government should have been $1,067,000 less than previously reported, or, in other words, that the Batavia Metal Products owed the government over a million dollars. A later audit reduced the figure somewhat.[95] In May the Batavia company agreed to repay the government $140,000 at once and $50,000 a month thereafter to liquidate the debt.[96] Mr. Royall referred the matter to the Department of Justice for advice and on 18 June 1946 Theron L. Caudle, Assistant Attorney General, wrote to Mr. Royall:

> If a criminal case should result from the Department's investigation of the Batavia Metal Products Co. and related companies, it is felt that acceptance of the contractor's offer would make successful prosecution more difficult. However, the investigation to date is not sufficiently complete for the Department to express any opinion as to whether a criminal case will develop, and therefore, no determination can be made at the present time as to the advisability of accepting the contractor's offer.[97]

Acting upon the advice of the Department of Justice, Mr. Royall made no move to accept payments under the terms suggested by the Batavia company.[98] Instead, the War Department, through the CWS, served a demand on Batavia Metal Products, Inc., to repay the excessive portion of the partial payment which had been made.[99] This demand against the Batavia company, which went into the hands of receivers in the fall of 1946, was never honored. In the spring of 1952 the case against the Batavia company, so far as its civil aspects were concerned, was nol-prossed by the government. But action against the Erie Basin company was to continue for a number of years.[100]

Flame Throwers

Portable Flame Throwers[101]

In April 1942 the CWS awarded a contract to the Beattie Manufacturing Co., Little Falls, N.J., a nationally known manufacturer of rugs and

[95] *Hearings*, pt. 35, Exhibit 1924, p. 19355.

[96] *Ibid.*

[97] *Hearings*, pt. 34, Exhibit 1899, p. 18181.

[98] *Ibid.*, p. 18181.

[99] Notes in history of Garsson contracts compiled by special agents of FBI in September and October 1946. CWS 314.7 Garsson Case File.

[100] Thirteen years after the close of the war the Department of Justice had two civil and one criminal cases pending against the Erie Basin Metal Products, Inc. and Erie Basin had two civil suits pending against the government.

[101] Unless otherwise indicated this section is based on: (1) History of New York CWPD, from 1940 through June 1944, pp. 198–224; (2) Interv, Hist Off with William Hewitt, inspector on the flame thrower in New York CWPD, and Alfred Benson, engineer in New York CWPD during World War II, 16 Mar 50; (3) Interv, Hist Off with Lawrence J. Beck, production engineer on portable flame thrower for Beattie Manufacturing Co. in World War II, 26 Nov 57; (4) *Alphabetic Listing of Major War Supply Contracts.*

carpets, for production of the M1A1 flame thrower, the development of which was well under way.[102] In mid-1941 this company had acquired the services of Lawrence J. Beck, an engineer who had worked closely with the CWS on the development and production of early model flame throwers. Beck's background and experience plus the company's standing in the business world virtually guaranteed creditable performances. In July 1943 the CWS engaged another prime contractor, the E. C. Brown Co., Rochester, N.Y., a manufacturer of agricultural sprayers, especially of the portable type. These two companies produced over 14,000 M1A1's in such an excellent manner that they were awarded contracts on the later model, the M2-2. In May 1944 a third contractor, R. F. Sedgley, Inc., of Philadelphia, was awarded a prime contract on the M2 model. Sedgley was a well known manufacturer of high grade sporting rifles. Over 24,500 M2-2 flame throwers were produced in 1944 and 1945.[103]

Of the three prime contractors, E. C. Brown was the most self-contained facility. This company manufactured production tools and made certain components not only for itself but also for the other two primes. Numerous subcontractors supplied components to all the primes—such items as pressure regulators, high pressure valves, safety heads, die castings, rubber components, and fuel filling lines. All contracts were under high priority, particularly after the ASF, in June 1944, issued an urgency circular describing the M2-2 as a "new and superior weapon."[104]

In the manufacture of the M2-2 the contractors used the latest techniques to insure uniformity and quality. All silver brazing on the gun assembly was done by induction heating and die cast aluminum parts were used for lightness and interchangeability. Corrosion resistant materials were used to withstand the effects of extreme climatic conditions. Complications arose in the manufacture of the fuel valve, the safety mechanism, and the outlet valve needle. The technique for the construction of the fuel valve, which consisted of a rubber diaphragm molded to a metal pin, was never fully developed, and on several occasions the service had to suspend production because of the number of rejects of this valve.[105] The safety mechanism had two objectionable features: it frequently pinched the operator's hand and it had a tendency to shift to the "off safety"

[102] See ch. VII above.
[103] CWS Report of Production, 1 January 1940 through 31 December 1945, p. 13.
[104] ASF Urgency Circular, 24 Jun 44, sub: Flame Thrower M2-2. Chicago CWPD 470.71 OC CWS Flame Throwers.
[105] The valve was very difficult to operate. Only a man with a large hand could open it.

position should the operator accidentally touch it. The outlet valve was difficult to adjust with the result that frequent leaks occurred. These defects were never entirely eliminated.

All the prime contractors built test ranges to proof test the flame throwers. These ranges were completely equipped to handle and service the weapon and its parts. Although the CWS and the contractors took safety measures to protect workers against the hazards involved in testing, three cases of severe burns occurred during the war period.

Auxiliary Flame Throwers

In December 1943, after a successful demonstration for representatives of the ASF, the CWS, the AGF, U.S. Marine Corps, and the Navy, production of the tank mounted auxiliary flame thrower (E4-5) was begun.[106] The CWS awarded a contract to the Kemp Manufacturing Co. of Baltimore to develop a pilot model. By early 1944 this company had devised a flame thrower consisting of a ten-gallon fuel tank, a gun utilizing a gasoline-electrical ignition system, and compressed air for propelling the flame.[107] Later an improved ten-gallon unit was developed jointly by the Westinghouse Electrical Corp., Atlantic Division, Philadelphia (also known as the Atlantic Elevator Co.), and J. B. Blair Co., Mineola, N.Y. These companies had produced fifty experimental models by the time the war came to an end.

Meanwhile the M3-4-3 auxiliary type flame thrower had been developed,[108] and the CWS awarded a production contract to the Atlantic Elevator Co. for production of these units. Over 1,700 were manufactured in 1944 and 1945.[109] The principal engineering difficulties in this type of flame thrower were the malfunctioning of the gasoline ignition valve, the faulty design of the diaphragm on the fuel discharge valve, and the clogging of the atomizer of the ignition system. Many units had to be rejected until these defects were rectified.

In November 1944 the CWS awarded a contract to Pressurelube Inc. for 500 periscope-type flame throwers.[110] The manufacture of the periscope type proved very troublesome. The ignition system failed to function unless

[106] Memo, CG AGF for CofS, U.S.A., attn: G-4, 10 Oct 44, sub: Mechanized Flame Throwers. AGF Cml Sec 470.71.

[107] *Ibid.*

[108] See ch. VII above.

[109] CWS Report of Production, 1 January 1940 through 31 December 1945, p. 13.

[110] See ch. VII above.

the air pressure in the gasoline tank was at a critical point between 12 and 30 pounds per square inch, and the exact point for each unit could be determined only by experience. Another obstacle was leakage in the fuel valve; in some instances this was caused by defective valve seals, in others by porosity in the valve housing. Technicians took steps to improve the valve by impregnating the castings with a polyspastic and cashew nut oil, by using different bronze alloys, and by improving manufacturing processes in the foundry. Pressurelube produced only 192 of the 500 units ordered.[111]

Main Armament Flame Throwers

Early in 1945 the CWS awarded prime contracts to M. W. Kellogg Co. of Jersey City and the Pullman Standard Car Co. of Hammond, Ind., for the main armament flame thrower (E12-7R1). They made little progress on the contracts largely because priorities for material were too low. The WPB upon request granted higher priorities for specific items but this procedure was time consuming. To rectify the situation, the Director of the New Developments Division, War Department Special Staff, Brig. Gen. William A. Borden, on 26 June 1945 suggested to the Assistant Chief of Staff, G-4, that, in view of reports from the Pacific areas indicating the great effectiveness of the armored flame thrower, the E12-7R1 project should be assigned a priority "equally as high as the Manhattan Project."[112] Upon reviewing General Borden's memorandum the Assistant Chief of Staff, G-4, passed it on to OPD for comment. Someone apparently brought the matter to the immediate attention of the Under Secretary of War, for the very next day the Under Secretary informed the Commanding General, ASF, that production of the E12-7R1 should have sufficient priority to insure delivery on schedule.[113] The following day—28 June—General MacArthur cabled the War Department urging that units be equipped with the E12-7R1 flame thrower.[114]

[111] (1) Historical Record of M3-4-E6R3 Mechanized Flame Thrower Contract, 20 Sep 45. Copy in CWS 314.7 Procurement File. (2) Hewitt interv, 16 Mar 50. (3) CWS Report of Production, 1 January 1940 through 31 December 1945, p. 13.

[112] DF, Brig Gen W. A. Borden, Dir New Developments Div to G-4, 26 Jun 45, sub: Production Status of Tank Flame Thrower, E12-7R1. OPD 470.71. By this time a number of mechanized units had been manufactured and assembled in the Middle Pacific Area and had been successfully employed in Pacific operations, especially on Okinawa. See Pritchard, Kleber, and Birdsell, Chemicals in Combat.

[113] See Memo for Record, 3 Jul 45, included with comment No. 3, C, Projected Logistics, with Ltr, OPD to G-4, 3 Jul 45, sub: Production Status of Tank Flame Thrower E12-7R1. OPD 470.71.

[114] CM-IN-27779 referred to in *ibid.*

The personal interest in the armored flame thrower displayed by echelons of the War Department and by General MacArthur led to accelerated production of the E12-7R1. On 4 July 1945 General Somervell wrote a personal letter to 83 subcontractors appealing to them to meet their schedules. In this letter he indicated that the War Production Board would be most co-operative in the matter of priorities and urged the contractors to take any problem or anticipated problem directly to a CWS officer whom he named as his personal representative. On 21 July the Industrial Division, OC CWS, reported to the Commanding General, ASF, that one or more telephone calls had been received from 21 of these contractors and letters from 23 others pledging co-operation. Late in July the acting director of Plans and Operations, ASF, was able to report to OPD that after the issuance of a triple A priority, 25 flame throwers were being produced in July, and 85 scheduled for August. Contemplated production for September ran to 115 and for each of the following three months to 175.[115] But the war ended before this scheduled production could be carried out.

Smoke and Smoke Munitions

Hexachloroethane (HC)

Hexachloroethane was the principal ingredient in making HC smoke mixture used in smoke pots, smoke grenades, smoke bombs, and certain types of shells and rockets. The prewar requirement for hexachloroethane was relatively small and the chief source of supply was the Pittsburg, Calif., plant of the Dow Chemical Co. The estimated capacity of that plant was about 3,000 tons a year, while the CWS requirements under the Army Supply Program (as of 14 January 1943) were 16,191 tons for 1943, and 33,222 tons for 1944. In order to fill immediate requirements the CWS contracted with a Canadian firm to deliver 2,500 tons late in 1942. At the same time, the service began writing contracts for future delivery with the Dow Chemical Co., the Hooker Electrochemical Co. of Niagara Falls, N.Y., and the Westvaco Chlorine Products Co. of South Charleston, W.Va.[116] In August 1942 the government started construction

[115] (1) Ltr, CG ASF to Eastman Manufacturing Co., Manitowoc, Wis., 4 Jul 45. Chicago CWPD 470.71 Flame Thrower 1944-45. (2) Memo, Actg C, Prod Br Ind Div OC CWS for CG ASF attn: Col G. D. Woods, 21 Jul 45, sub: Results of General Somervell's letter of 4 July to Subcontractors of the Mechanized Flame Thrower. ASF 470.71 Flamethrower. (3) Memo, Actg Dir Plans and Opns ASF for Asst CofS OPD WDGS, 27 Jul 45, sub: Main Armament Flame Throwers E12-7R1. OPD 470.71.

[116] Dow Chemical Co. was to produce the product at Freeport, Tex.

of the CWS Kanawha Plant adjacent to the property of the Westvaco Chlorine Products Co. The following summer the CWS Marshall Plant at New Martinsville, W.Va., was erected for the production of hexachloroethane and other chemicals and a contract awarded to Du Pont to operate the plant. From these various sources the CWS procured over 9,000,000 pounds of hexachloroethane in 1943 and almost 8,000,000 pounds in 1944.[117]

In 1943 a priority problem arose on perchlorethylene, the chief ingredient of hexachloroethane. Perchlorethylene is produced from acetylene tetrachloride, which is also the source of chemicals used in degreasing metal parts and in dry cleaning. The CWS had to work closely with the War Production Board to set up a schedule that would guarantee perchlorethylene in sufficient quantities.

Among the munitions filled with HC smoke mixture were 2-pound bombs, M8 grenades, rifle smoke grenades, M88 and M89 shells, canisters for 105-mm. and 155-mm. shells, 100-pound and 500-pound clusters, 2.35-inch rockets, and smoke pots. Virtually all the 2-pound bombs were loaded under private contract in the Pittsburgh and Chicago procurement districts. Rifle grenades, smoke shells, and canisters were loaded at CWS arsenals, particularly Huntsville and Pine Bluff. Edgewood Arsenal filled all 100- and 500-pound clusters.[118]

The M1 smoke pots were manufactured and filled at Huntsville and Pine Bluff Arsenals and under contract in the New York and Dallas procurement districts. The latter districts also procured all the M5 smoke pots. Maintaining safety in the loading plants took constant attention. The creation of static sparks was an ever present possibility and to eliminate it a high degree of humidity had to be maintained in the plants. The tragic experience of one of the contractors with a poorly designed air conditioning system pointed up the need for extreme care. Because of the scarcity of raw materials this company set up a system wherein all the air conditioning ducts throughout the entire plant were connected. One day a fire broke out in one of the explosive-proof cubicles. The fire itself proved

[117] (1) History of the New York CWPD, June 1940 through June 1944, vol. 1, pp. 181-85. (2) Chemical Warfare Presentation SOS Staff Conference, 14 Jan 43, sub: Procurement and Production Problems, CWS 337, 1943. (3) Memo, Dir of Req Div SOS for C CWS, sub: Production of Hexachloroethane. CWS 334.8, Chemical Warfare Production. (4) History of Kanawha Plant, CWS, p. 22. (5) History of the Marshall Plant, CWS p. 1. CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 17.

[118] CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 5, 7, 11, 16, 26.

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relatively harmless, but the air cooling system spread the smoke created by the burning HC mix throughout every room and department of the plant. So thick was the smoke that workers could not find doors and windows only a few feet away. Two employees suffocated. This experience led the Plant Protection and Safety Branch, OC CWS, to rule that air conditioning systems should have elaborate automatic safety cutoffs and that in all future installations each section of a plant should have a separate air conditioning system.[119] During the war the CWS procured over 5,000,000 M1 and over 880,000 M5 smoke pots.[120] The service also procured a great quantity of floating smoke pots for use in amphibious operations. Almost all of these—over 2,000,000—were filled at Huntsville Arsenal.[121] The loading process consisted of pressing the 26 pounds of HC mix into the 5-gallon buckets with 8 tons of dead weight. A delay train ignition device, which consisted of a pyrotechnic mixture pressed into a metal tube, was attached to the lid. The lid was then strapped on the bucket, after which the pot was ready for packing. At first wooden boxes were used for packing but later these were replaced by steel drums. As in the case of other type smoke pots, the loading of the floating pot presented hazards. In pressing the mix into the buckets a certain portion was forced out as dust. To overcome this health and safety hazard Huntsville Arsenal constructed shields to force the dust back to the base of the presses.[122]

White Phosphorus (WP)

In August 1941 the CWS awarded a contract for delivery of white phosphorus, the smoke and incendiary agent, to the Victor Chemical

[119] G. B. Spencer-Strong, "Pemco War Story," *Armed Forces Chemical Journal,* III (October 1948), 53–55.

[120] CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 25.

[121] *Ibid.*

[122] History of Huntsville Arsenal from July 1941 to August 1945, vol. II, pp. 534–38.

Works. The Victor company's Mount Pleasant, Tenn., plant supplied Edgewood Arsenal with the material until December 1941. After the outbreak of war the CWS procured the bulk of its WP from Tennessee Valley Authority (Wilson Dam, Ala.) although between April 1943 and April 1946 it also obtained some from the Columbia, Tenn., plant of the Monsanto Chemical Co.[123] Two conditions necessary for producing WP are proximity to phosphate rock deposits and a cheap source of electricity.[124] The CWS arranged to have most of TVA's product shipped to Huntsville Arsenal, since transportation was relatively direct and inexpensive between these two points. The Monsanto plant supplied the other three CWS arsenals as well as the Ferro Enamel Co., Cleveland, Ohio, which also filled some WP munitions.[125]

Shipping WP to the loading plants presented a problem. Because the chemical burned upon contact with air, it had to be shipped under a covering of water. Trained operators filled the white phosphorus in liquid form into tank cars or trucks, which were insulated with 4 inches of rock wool and equipped with steam coils. The CWS bought 25 of these tank cars and 10 trailer trucks, the latter for the exclusive use of Huntsville Arsenal. Before the phosphorus was poured in, the tanks were partially filled with water, all but a small portion of which was to be replaced by the WP. The workmen had to exercise great care to make certain that *all* the water was not replaced by the chemical, else a fire would occur. On a short journey the chemical remained in liquid form and was unloaded at its destination by a reverse process, that is, by forcing a sufficient quantity of water into the tank to replace the WP. On a long journey the material solidified and the tanks had to be treated with steam to liquefy the WP and make it ready for unloading. It was essential that the tanks be unloaded without undue delay because the combination of the phosphorus and water produced a weak solution of sulphuric acid which attacked steel. The material had to be stored in concrete structures.

White phosphorus was loaded into artillery shells, 4.2-inch chemical mortar shells, 30-pound M46 bombs, and 100-pound M47 bombs, M15 hand grenades, explosive type igniters, and 3.5-inch and 4.5-inch rockets. It was also loaded into catalin, bakelite, or glass containers, which in turn

[123] *Alphabetic Listing of Major War Supply Contracts,* vol. 3, p. 2137; vol. 4, p. 3075, and p. 3262.

[124] For an excellent account of the growth of the phosphorous industry see Christian H. Aall, "The American Phosphorus Industry," *Industrial and Engineering Chemistry,* 7 (July 52), 1520–25.

[125] Interv, Hist Off with Maj Eugene F. Lennon, Jr, 16 May 58.

served as ignition charges in the M74, M69, and M69X incendiary bombs. In the loading process the munitions were filled with hot liquid phosphorus under water and then cooled to solidify the WP in such a way as to maintain proper ballistic properties.[126]

The CWS conducted training courses for phosphorus fillers and press operators at Edgewood Arsenal, to which key individuals from other arsenals were sent for periods of from thirty to ninety days. Upon their return to their home stations these workers trained others in the various procedures.[127]

Smoke Generators

Immediately after the attack on Pearl Harbor a demand arose for stationary smoke generators in the Panama Canal Zone and in the Western Defense Command. The OC CWS allocated procurement of this item to the Chicago procurement district office. Early in February 1942 the Chicago office drew up a contract with Gendar, Paeschke and Frey Co. of Milwaukee to produce about 10,000 stationary generators in 30 days. At the same time contracts for parts were drawn up with the Grand Sheet Metal Co. of Chicago and dozens of small sheet metal shops in the Chicago vicinity. A big problem was obtaining the 5,000 tons of 18-gauge sheet steel to fabricate the generators. A search revealed that the Ford Motor Co. in Detroit could spare this quantity of steel and the procurement district office arranged for transporting it to Milwaukee. Late in February an express trainload of stationary generators and auxiliary equipment was rolling to the New Orleans port of embarkation, destination MERCURY.[128]

The CWS was responsible not only for the procurement of the generator itself but also for a list of some 35 auxiliary items. These items included 10,000-gallon bolted steel tanks for storing the fuel oil, 750-gallon refueling units mounted on Army 2½-ton trucks, 55-gallon drums, funnels, and torch igniters.[129]

By the fall of 1942, 123,800 smoke generators had been procured. Of this number 55,800 were in the hands of smoke generator companies in

[126] (1) CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 5, 14, 17, 26, 28, 29, 30. (2) Hist of Huntsville Arsenal from July 1941 to August 1945, vol. 1, 483–505. (3) Preliminary History of Pine Bluff Arsenal, World War II, sec. VII. (4) History of Rocky Mountain Arsenal, vol. IX, 2918–58, 3165–83. (5) Lennon Interv, 16 May 58.

[127] History of Huntsville Arsenal from July 1941 to August 1945, vol 1, p. 497.

[128] (1) The code name for Panama. (2) History of Chicago CWPD, 1 Jan 45–15 Aug 45, p. 76.

[129] *Ibid.*

the Canal Zone, at the Sault Ste. Marie Canal, and at aircraft factories on the west coast. Companies found that it was difficult to move the large bulky generators quickly when the wind changed, and this disadvantage, coupled with the development of better generators, led the service to abandon the device in 1944.[130]

In mid-1942 the CWS let a contract through the Chicago procurement district to the Heil Co. of Milwaukee for the manufacture of the M1 mechanical generator.[131] This company worked closely with CWS technicians and representatives of the Standard Oil Development Co. on production difficulties. Among the serious production problems encountered was a tendency of the oil burners to overheat; this was solved by installing temperature regulators on the burners. Another difficulty was obtaining efficient pumps for the water and oil. The CWS procured over a thousand of these models.[132]

The Besler Corp., Emeryville, Calif., which was mainly responsible for developing the M-2 mechanical smoke generator, was the sole prime contractor for this item.[133] Besler, whose peacetime business was the engineering, developing, and building of high pressure generating units and engines, had already manufactured somewhat similar units for the Navy. Consequently, no outstanding production manufacturing troubles arose. The Clayton Manufacturing Co., Alhambra, Calif., the chief subcontractor, cooperated in an excellent manner in furnishing parts. Over 2,700 M2s were procured and shipped overseas.[134]

Airplane Smoke Tanks [135]

The CWS procured all airplane smoke tanks through its Chicago district. By far the greatest number—over ninety-two thousand—was of the

[130] (1) Memo for Record, Maj Delancey R. King, Opns Br OC CWS, 15 Sep 42, sub: Generators, Smoke, Stationary, M1. CWS 320.2/207. (2) CWTC Item 1010, Obsoletion of Generator, Oil, Smoke, M1, 5 May 44. (3) CWTC Item 1073, same title, 7 Jul 44.

[131] The M1 mechanical generator was standardized in Jan 43. See ch. IX, above.

[132] (1) History of Chicago CWPD, 1 January 1945–15 August 1945, p. 62. (2) Ltr, C Insp Div OC CWS to Insp Off Chicago CWPD, 6 Jun 44, sub: Inspection, Generator, Smoke, Mechanical, M1 (100 gallons). CWS 319.1, ETOUSA 1944. CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 14.

[133] See ch IX above.

[134] (1) History of San Francisco CWPD, 1940–1945, pp. 78–80. (2) CWS Report of Production, 1 Jan 40 through 31 Dec 45, p. 14. (3) Interv, Hist Off with John A. Panella, 13 Mar 57. Mr. Panella, then a CWS officer, was in charge of the M2 smoke generator program in San Francisco CWPD in World War II.

[135] This section is based on History of Chicago CWPD, 1 Jan 45–15 Aug 45, pp. 71–72, and CWS Report of Production, 1 Jan 45–31 Dec 45, p. 31.

M10 type, which was wing mounted and expendable. Over ten thousand each of the M33 and M33A1 models were procured. These models, which were mounted in the bomb bays of the planes, were not expendable. As indicated above, some M20's and M21's were procured before decision was made to abandon these models.[136]

The principal contractor for smoke tanks was the Empire Stove Co., Belleville, Ill. Other contractors were the James Manufacturing Co., Fort Atkinson, Wis., and the National Roadjoint Manufacturing Co. of Chicago. The contracts called not only for the delivery of the tanks but also of such parts as wrenches, elbows, air inlet plates, and plate closures. A hitch was encountered in the procurement of the parts by the shortage of copper bearing steel. In the installation of the M33 and M33A1 models a difficulty arose in developing satisfactory mounting lugs and braces. Both the Navy and the Air Forces co-operated closely with the CWS in resolving this matter.

Colored Smoke Munitions[137]

The loading of colored smoke munitions was confined to two CWS arsenals, Edgewood and Huntsville. By far, most of the loading was done at Huntsville. There the colored smoke was loaded into M16 and M18 grenades, and M22 and M23 rifle grenades, furnished by the Ordnance Department, and canisters for 105-mm. and 155-mm. Ordnance shells.

The job of loading these munitions raised a number of problems which were solved on a pragmatic basis. For example, when the production of M16 grenades was initiated in the fall of 1942 a hazard was created in filling the grenade with the dry mix, the dust of which caused fires and explosions. To overcome this hazard the dry mix was placed in a dough mixer and granulated with water. In the spring of 1943, when the schedule for M16 grenades was increased, a quicker method of filling had to be found. Huntsville Arsenal experimented with a Stokes-Smith filling machine using dry mix instead of granulated mix. This method proved successful for red and violet grenades, but not for yellow and green grenades, because the latter were more sensitive; consequently, they continued to be loaded by the granulated method. The finished batch of mix was tested by filling two grenades and firing them. If the grenades functioned accord-

[136] See ch. IX above.

[137] This section is based on History of Huntsville Arsenal, July 1941 to August 1945, vol. II, 664–75 and CWS Report of Production, 1 Jan 40 through 31 Dec 45, pp. 6, 7, 15.

ing to specifications the mix was used in the filling line; if not, it was reworked. In filling the M16 three increments were used, each increment being subjected to pressure of about two tons. As a preventative against dust, fuel oil was poured into the mix in the filling machine.

In loading the M16 grenades, and all other colored smoke munitions, safety was the biggest problem. The danger of fire from dust and other causes was always present. Workers had to wear fireproofed clothing and safety shoes at all times. The plants had to have sprinkler systems, and the workers had to be taught how to use them. Dust was not only a fire hazard, but it also caused some workers to become ill for several hours at a stretch.

Problem of Morale

Complications arose in storing and issuing chemical warfare matériel no less than in its procurement. These complications began to appear in the emergency period and continued to challenge the CWS throughout the period of the war.

Notwithstanding the hazards inherent in the operation of chemical warfare plants, the CWS and its contractors did obtain the services of a body of loyal and efficient workers. When one considers these hazards together with the difficulties besetting the mass production of certain chemical warfare items, it is not surprising that the CWS was sensitive to the need for maintaining a high level of morale. The chief's office initiated the practice of sending military officers who were on production assignments to Dugway Proving Ground to witness demonstrations of airplanes dropping incendiaries on specially built targets. These visits gave the officers an opportunity to see in action the munitions they had labored to produce. If there were any duds the officers were impressed with the need for producing only high grade matériel. Civilian workers at the arsenals and plants, many of whom were wives of servicemen, were spurred on by motion pictures depicting the effectiveness of chemical warfare munitions as well as through lectures given by soldiers who had been overseas.

The contractors, no less than military and civilian workers, needed incentives to bring out their maximum potentialities. Problems associated with CWS procurement had particular implications for the contractors. In the matter of priorities, for example, a manufacturer who was faced with a low priority would naturally tend to assume that his product was not so important as others. He would, moreover, be put in the embarrassing

position of having his work interrupted for lack of materials and labor without any provision being made for equitable compensation. Again, frequent changes in drawings and specifications resulting from the backward state of development of a number of chemical warfare items caused frustration among contractors. Sometimes the contractors would but recently have succeeded in mastering the manufacturing techniques on a certain model when a change would come along. Another source of irritation was the frequent revisions in production schedules resulting usually from a change in Army requirements. These changes might lead to cancellation of contracts or to the need for setting up new assembly lines with consequent dislocation of workers. Another possible source of annoyance was the inspection standards on certain items such as the gas mask. Regardless of the merits or lack of merit of certain CWS inspection procedures, the fact was that many contractors resented the procedures.

The principal medium for improving morale of contractors was the Army-Navy E (for Excellent) award. The quality and quantity of the contractor's production in the light of the facilities available to him were prime considerations in selecting recipients for this award. Other criteria included the contractor's record in (1) overcoming production obstacles; (2) avoiding work stoppages; (3) maintaining fair labor standards; (4) training additional labor forces; (5) managing his business effectively; (6) maintaining a safe and sanitary plant; and (7) utilizing subcontracting facilities. Final selection of Army recipients for E awards rested with the Army Board for Production Awards appointed by the Under Secretary of War.[138]

The CWS presented over 150 E awards during the war. In the granting of two of these awards, those to Erie Basin Metal Products, Inc., and to Batavia Metal Products, Inc., the CWS is open to criticism. The lack of co-operation on the part of these contractors in connection with the pricing program in the CWS would in itself seem to have been sufficient reason for precluding them from the awards. But their records on labor turnover and on use of facilities were also bad. These facts came to public notice in the open hearings before the Special Committee of the U.S. Senate Investigating the National Defense Program in July 1946. There it was revealed that the former wartime chiefs of the Chicago Ordnance District offices, Brig. Gen. Thomas S. Hammond and Col. John Slezak, steadfastly refused to recommend these contractors for E awards. To quote Gen-

[138] Army-Navy Production Award Manual, pp. 4–4a. CWS 314.7 "E" Awards File.

eral Hammond, "If you gave the E award to them, the E award wasn't worth very much in the Fox River Valley after that."[139]

But there is good reason for believing that the E awards granted to the Erie Basin and Batavia Metals companies were the exception to the rule among CWS contractors. The standards for this award were very high—perhaps somewhat too high—and most of those who received it deserve the highest praise. There is little doubt that the other CWS contractors who got the E award richly deserved the honor.

[139] *Hearings,* pt. 34, p. 17894.

CHAPTER XVI

Storage and Distribution

Growth of CWS Storage Activities

During the months before Pearl Harbor, new logistics responsibilities assigned to the Chemical Warfare Service led to major changes in storage facilities. The principal problems at the beginning of 1941 had been the storage of mobilization quantities of gas masks (and, to a lesser extent, the storage of toxic gases). The Army's September 1941 call for CWS procurement of incendiary bombs and 4.2-inch mortar shells introduced a whole new set of storage needs, and greatly enlarged the scale of facilities planning. There could be no storage of bombs and shells in urban warehouses, nor was there space at Edgewood for the many new magazines which would be required.[1] As early as the winter of 1940–41 the CWS had to lease large warehouses in Chicago and Indianapolis for storing items delivered by contractors, and the Indianapolis installation was subsequently (April 1942) to become a full-fledged depot. But far more than this was needed. New depots had to be quickly planned. The first was an addition to the recently authorized CWS Huntsville Arsenal which the Army was building in northern Alabama. Action for this facility, the future Gulf Chemical Warfare Depot, began in September 1941 with an authorization for the transfer of 282,000 square feet of proposed toxic gas storage yard construction from Edgewood to Huntsville.[2] In November the Army informed the OC CWS that funds would be available to provide storage for 40,000,000 four-pound incendiary bombs. The planned Huntsville depot gained half the

[1] See ch. XI above for description of storage facilities at Edgewood.

[2] (1) Ltr, Col P. X. English, C Ind Div OC CWS, to QMG, 23 Aug 41. CWS 681/29. (2) Memo, Col H. S. Aurand, C Req & Dist Br G–4, for Construction Br, 10 Sep 41, sub: Depot Storage Program (Deferred Storage). G–4/32315 Sec I.

number of magazines needed to fill this requirement, while the remainder was scheduled for construction at Pine Bluff, Ark., like Huntsville the site of a new CWS arsenal.[3] During 1942 the storage area at Pine Bluff became the nucleus of another new depot, Midwest.

As soon as the country was actually at war, the Chemical Warfare Service took steps to provide itself with a major depot in the far west. The preferred location was the Salt Lake City area, and a desert valley some fifty-seven miles southwest of the city, in Tooele County, Utah, was selected in February 1942. The new facility, designated Deseret Chemical Warfare Depot, was under construction by the summer of 1942. Its principal function was to serve as another storage center for bombs, mortar shells, and toxics.[4]

Within a year of the attack on Pearl Harbor, therefore, the wartime storage requirements of the Chemical Warfare Service were well on the way toward being matched by Chemical Warfare facilities. In addition to the prewar storage areas at Edgewood and Indianapolis, new depots were virtually complete at the sites of the Pine Bluff and Huntsville Arsenals, while the Deseret Depot was being hurried into existence. Deseret began its active storage operations in October 1942, despite the fact that construction was still underway; the depots at Pine Bluff and Huntsville had been operating since summer. From some 2,500,000 square feet of storage space in June 1942, the total available to the CWS jumped to 19,500,000 square feet by the end of 1942 and to 23,000,000 square feet by the following June.[5]

With the activation of the new depots the CWS depot system consisted of five branch depots—Eastern (Edgewood), Gulf (Huntsville), Midwest (Pine Bluff), Indianapolis, and Deseret—and five chemical sections of Army Service Forces depots—Atlanta, Memphis, New Cumberland, San Antonio, and Utah.[6] The missions of these installations varied considerably. The Indianapolis Depot became in effect (and eventually in name) a national control point for CWS spare parts.[7] The other branch depots had in common a responsibility for reserve storage of CWS gen-

[3] Memo, C Fld Svc OC CWS for C Ind Svc, OC CWS, 13 Nov 41. CWS 471.6 Bombs.

[4] (1) History of the Deseret Chemical Warfare Depot to June 30, 1945, pp. 1–13. (2) Ltr, TAG to C CWS, 14 Jul 42, sub: Designation of Deseret Chemical Warfare Depot. AG 681 (7–9–42) MR–M.

[5] Cf Baum, Brophy, and Hemleben, Chemical Warfare Service Supply Program, pt. 4, Storage and Maintenance, p. 637, and Table 9.

[6] A sixth branch depot, Northeast, was activated in mid-1944 near Niagara Falls, N.Y., to serve as an ammunition subdepot of Edgewood.

[7] See ch. XIII above.

TABLE 9—CWS GROSS STORAGE SPACE IN OPERATION, 1945

[In Thousands of Square Feet]

	Warehouse	Shed	Igloo Magazine	Toxic Yard	Open	Total
Totals	3,866	107	1,656	20,632	3,257	29,518
Eastern CWD	306	13	115	258	188	880
Indianapolis CWD	233				78	311
Gulf CWD	708		624	868	1,185	3,385
Midwest CWD	134	3	486	1,453	445	2,521
Deseret CWD	78		304	18,053	631	19,066
Northeast CWD	13		90		132	235
New Cumberland ASFD	380	32			301	713
Atlanta ASFD	212		9		264	485
Memphis ASFD	254	49	5		16	324
San Antonio ASFD	161		6		2	169
Utah ASFD	568	10	17		15	610
Chicago Warehouse [a]	247					247
New York Warehouse [a]	216					216
Hanford (Cal.) Warehouse [a]	68					68
Independence (Cal.) Warehouse [a]	68					68
San Francisco POE [b]	89					89
New York POE [b]	131					131

[a] CE, Quarterly Inventory, Sponsored, and Leased Facilities, 31 Dec 44.

[b] Hemleben, CWS Activities at Ports of Embarkation, pp. 142, 206, 213. Approximately 15,000 sq. ft. of CWS warehouse storage space was in use by the Port Chemical Officers at the smaller Ports of Embarkation.

Source: ASF MPR-2-H, 31 Mar 45, p. 39, except as noted.

eral supplies, but their main mission was the handling of chemical ammunition and toxics for zone of interior distribution, shipment to Ports of Embarkation, and reserve storage. Distribution of general supplies, both for zone of interior installations and the Ports of Embarkation, was handled in the main by the Chemical Sections of the ASF Depots, which also distributed training ammunition to their local Service Commands.[8]

One of the early concerns of the new Headquarters, Services of Supply, in the spring of 1942 was supervising and standardizing Technical Service depot activities. Immediately upon its activation the SOS called upon a group of commercial warehousemen to help solve Army warehousing problems. This group, working at the San Antonio General Depot, introduced a number of innovations into Army storage practices. Among these were the reduction of aisle space to a minimum by eliminating inventory aisles, and the mechanization of materials handling through the

[8] Supply Mission statements of the branch depots and chemical sections may be found in S. J. Hemleben and E. M. Loughery, Hist of CWS in World War II, vol. IV, Chemical Warfare Service Supply Program, pt. V, Distribution, app. A. (MS Monograph).

use of fork-lift trucks and palletized loads.[9] The CWS belatedly profited from the lack of peacetime expansion of storage facilities in that it could build the new depots along lines of contemporary storage practices and wartime Army requirements. At the prewar Eastern Depot at Edgewood storage space was distributed among a number of small buildings, all with floors at ground, rather than boxcar, level. The new CWS depots, on the other hand, were designed for more efficient concentration of storage, within limits of safety, and all had floors at boxcar level. The savings in aisle space and labor made possible by the new Army guidelines promised to be considerable.[10]

The mechanization of materials handling at CWS depots began on a small scale during the summer and fall of 1942, in accordance with SOS policy and directives. The process of change was slow at first. Indianapolis Depot was using half a dozen fork-lift trucks for stacking matériel as early as July 1942.[11] Gulf Depot, which had begun operations on "whiskey and manpower" in the spring of 1942, received its first fork-lift trucks in October, along with some warehouse tractors.[12] Midwest and Deseret were operating fork-lift trucks by the spring of 1943, but Eastern Depot, with its complicated physical layout, did not begin this phase of mechanized storage until February 1944.[13] Northeast Depot, activated in the spring of 1944, well after the early days of mechanization, used fork-lift trucks from the outset.[14]

The fork-lift truck made possible a number of labor- and space-saving advances in storage techniques. Chief of these was the palletized load, a unit of storage consisting of a pallet or wooden platform of a size to hold a given quantity of material, and built to leave clearance underneath for the forks of the fork-lift truck. Palletized loads, capable of being moved quickly into place with the fork-lift trucks, could be stored to considerable heights without danger of damage, thus making possible more economical use of space as well as of time and labor.[15] Fork-lift trucks were also used in

[9] (1) ICAF R 39, Handling of Materiel, Nov 45, p. 9. ICAF Library. (2) Millett, *The Organization and Role of the Army Service Forces,* p. 300.

[10] Memo, Maj W. C. Crosby, WD General Depot Service, to Col A. B. Drake, 2 Jul 42, sub: Inspection of Edgewood CWS Depot. ASF A46-139, Eastern CW Depot.

[11] History of the Indianapolis CWD, May 1942-July 1945, p. 63.

[12] History of the Gulf CWD, 6 March 1942 to 15 August 1945, pp. 5, 10.

[13] (1) History of Midwest CWD, 2 August 1945, vol. I, pp. 60-62. (2) History of Deseret CWD to June 30, 1945, pp. 25, 28. (3) History of Eastern CWD to June 1945, pp. 107-08.

[14] History of Northeast CWD, June 1944-August 1945, pp. 8-10.

[15] For a more complete description of palletizing, see Risch, *Organization, Supply, and Services,* pp. 347-49.

conjunction with many jigs, booms, and claw devices, most of them on-the-spot expedients, to improve the handling of bulky items. Deseret had a jig and boom attachment to the fork-lift truck in operation for unloading freight cars by October 1943. Jigs for simultaneous handling of up to nine 55-gallon drums of toxics were in use there during 1944, and similar methods came into use for loading the awkward incendiary bomb clusters.[16]

BOXED CANS OF DECONTAMINATING SOLUTION *stacked on pallets, wooden platforms built to leave clearance underneath for the forks of the fork-lift truck.*

By 1944 the use of mechanized handling equipment had become general in CWS depots, and the savings in man-hours began to loom large. Eastern Depot found that the 40 man-hours previously needed to unload a boxcar could be cut to 20 or less, with 5 men doing the work of 10.[17] Deseret cut crew time for the unloading of 100-lb incendiary clusters from 5 hours to 1 hour per car by using fork-lift trucks with homemade jigs.[18] But fork-lift trucks brought problems as well as savings. Eastern Depot, which had never been built for mechanized handling equipment, frequently found itself in difficulties on this score. Its sixty-odd ground-level storage structures, scattered over two main areas a mile and half apart, made it hard even to get trucks from building to building, for they were not designed for cross-country operation. The trucks ultimately had to be mounted on low trailers constructed for the purpose, and towed from place to place by tractor. The depot also found that it needed an unusually large number of pallets if enough were to be on hand in any given area when required. By 1945 there were no fewer than 35,000 pallets of various sizes on the depot grounds.[19]

[16] History of Deseret CWD, pp. 37–45.
[17] History of Eastern CWD, pp. 107–08.
[18] History of Deseret CWD, p. 42.
[19] History of Eastern CWD, pp. 108–11.

Storage and Transportation of Toxics

The problems of handling war-swollen stocks of general supplies by up-to-date methods came upon the CWS suddenly, but the task of storing items such as toxic agents was hardly new. The methods for storing and handling agents in bulk had been worked out during and after World War I by Edgewood Arsenal. The principal packaging device for toxics was the ton container, a steel cylinder with a capacity of 170 gallons (about 1900 pounds in the case of mustard). These were kept in open storage, resting horizontally on tracks designed to keep them off the ground and assure free circulation of air.

Edgewood had developed a deep respect for the problems inherent in handling and storing toxic agents and had worked out special techniques for testing, cleaning, and handling toxic containers. Men classified as toxic gas handlers had demonstrated an aptitude for the work and completed a special training course. This experience with a training program proved its value in another way after Pearl Harbor, when the depot at Edgewood found itself obligated to train cadres of toxic gas handlers for the new depots under construction.[20] Midwest Depot, for example, sent seven enlisted men to the course at Edgewood in the summer of 1942 as the first step in getting its projected toxic yard into operation.

With the exception of Indianapolis, the new depots were meant to assume most of the responsibility for the storage of toxics. While Eastern was reaching its wartime maximum of some quarter of a million square feet of toxic yard space, its younger counterparts were hurrying to completion toxic yards which multiplied Eastern's size many times over. Deseret alone had a toxic yard potential of over eighteen million square feet, and Midwest and Gulf had 2,300,000 square feet between them. But in the early days of wartime production it sometimes seemed as if storage space would never catch up with the demand. At Midwest Depot in 1942 the first shipment of toxics—525 ton containers of mustard—arrived just in time to fill the storage tracks available, and for the next eleven weeks construction of additional trackage was matched week after week by fresh shipments.[21] Shipments of toxics into Deseret became necessary in October of 1942, though the depot had been only four months under construction. Over two thousand tons of mustard were received and stored there by mid-November, though most of the necessary mechanical handling equip-

[20] *Ibid.*, pp. 122–27.
[21] History of Midwest CWD, p. 86.

ment was still lacking and the crews were still without permanent living quarters.[22]

The maintenance of toxics in storage involved a number of special problems arising from the nature of the materials. Mustard, which constituted by weight well over half of all the toxics produced by the CWS, required particular attention. In the form produced during most of the wartime period (the so-called Levinstein H) it contained about 30 percent of more or less unstable impurities which introduced some complicating factors when it was left in storage for any length of time. It evolved gases at a rate which sometimes built up dangerous amounts of pressure within the containers. It deposited tarry sludges which could not be drained out. Handlers had to learn techniques for testing pressures in containers, venting them when necessary, and cleaning them after they were drained. The possibility of leakage was always present, and with it the likelihood that other containers near the leaking one would become contaminated. Midwest Depot found it necessary at one time to segregate a large number of suspect toxic-filled containers in a "sick bay" to keep them from contaminating the rest of the toxic yard when, as sometimes happened, a combination of corrosion and high pressure produced a sudden spray of mustard through a leak.[23]

When toxics were stored in 55-gallon drums instead of ton containers, as necessity or convenience sometimes required, problems of corrosion and leakage multiplied. If the drums were shipped and stored standing on end they were likely to trap rain water on top and rust. If they were placed on their sides some of the bungs at the ends were likely to leak. Eventually CWS decided that in depots, at least, it was better to leave the drums on their sides and keep inspecting them for leaks, than to risk accelerated corrosion through rusting.[24]

In view of the undependability of containers and the highly dangerous character of toxic agents, it was very important that shipments of toxics be accompanied by guard details trained to handle such materials and to recognize and deal with potential sources of trouble. When large-scale shipments of toxics in and out of depots began in 1942, trained servicemen were picked up wherever they were available to act as guards and

[22] History of Deseret CWD, pp. 23–26.

[23] History of Midwest CWD, pp. 92–93.

[24] Ltr, CO Pine Bluff Depot [Midwest] to C CWS, attn: Supply Br, 15 Apr 43, sub: Storage of 55-Gallon Drums for HS and 1st Ind, Col N. D. Gillet to CO, Pine Bluff Depot, 21 Apr 43. CWS 457–PBA–1943.

TOXIC GAS YARDS, MIDWEST CHEMICAL WARFARE DEPOT, *Pine Bluff Arsenal, Arkansas.*

handlers. The first trainload of mustard from Huntsville Arsenal to the toxic yard at Midwest Depot, for example, was convoyed by the first 7 men the depot had sent to Edgewood for training as toxic gas handlers; they were simply detailed to stop off at Huntsville on their way back from Edgewood in order to accompany the train.[25] In other cases the installation originating shipment provided a guard detail from its own military personnel to act as convoy.[26] It seemed advisable as time went on to provide a centrally available and uniformly trained detachment to handle all convoy duties incident to the shipment of toxics and chemical munitions. Accordingly, in January 1943, on the recommendation of OC CWS, the Services of Supply directed the Chemical Warfare Service training center at Camp Sibert, Ala., to set up and train a detachment of 20 officers and 100 enlisted men for service as a guard and security unit for the shipment of toxics.[27]

The unit was duly brought into being at Camp Sibert as a section of the RTC Specialist Schools. Its enlisted men came from the 1st and 2nd

[25] History of Midwest CWD, pp. 85–86.

[26] History of Guard and Security and Tech Escort Detachment, December 1954, p. 7. Hereafter cited as Guard and Security.

[27] Ltr, OC CWS to CG SOS, 20 Jan 43, sub: Military Personnel to Accompany Shipments of Classified Chemical Warfare Material. CWS SPCWP 210.482/3.

Regiments of the RTC, and the officers were attached from the CW Officers' Replacement Pool. On 1 February 1944 the unit was transferred to Headquarters Detachment I, Chemical Warfare Center at Edgewood, where it remained for the rest of the war. Its strength rose to a wartime peak of about three hundred and fifty officers and enlisted men.[28] The unit carried on a three-week training program for all men assigned to it.

Within the zone of the interior the principal job performed by the guard and security unit was to escort rail shipments of toxics and toxic filled munitions to and from depots, arsenals, and ports of embarkation. A guard detail, headed by a junior officer, took custody of each shipment at its point of departure, accompanied it via railroad caboose throughout its journey, maintained a continual alert for emergencies, checked the cars for evidence of contamination at each stop, and made detailed inspection of the condition of the shipment during major stopovers. All leaks found in containers or casings were repaired. Cars found to be contaminated through extensive leakages of toxics were promptly sidelined and guarded until they could be decontaminated or the contents reloaded.[29]

If the shipment was bound overseas, the guard detail went overseas with it. It supervised loading on shipboard and also guarded the matériel. While at sea it kept a daily check of the ship's ventilating system to make sure that no toxic vapors were contaminating the air. The crew was equipped with gas masks and given instruction by the detail in gas mask drill, first aid, and decontamination. After the destination was reached, the cargo was inspected again before being unloaded.[30]

Storage of Other CWS Items

Incendiary Bombs

The transfer to the Chemical Warfare Service of responsibility for the incendiary bomb program in the late summer of 1941 brought with it the need for magazine operations on a scale hitherto reserved for Ordnance. Storage requirements for items capable of explosive or incendiary behavior—both of which could be expected from incendiary bombs in case of accidents—followed a fairly strict pattern based largely on Ordnance experi-

[28] Guard and Security, pp. 7–11, 18.

[29] (1) 1st Ind Hq Guard and Security Division, CWS, 20 Dec 44, to Ltr, Maj H. J. Isbell, Training Div OC CWS, 18 Dec 44. CWS 314.7 Storage File. (2) Guard and Security, pp. 20–23.

[30] Guard and Security, pp. 24, 25.

ence with ammunition storage. From 1928 onward the typical Ordnance high-caliber ammunition magazine had been built in the form of what was called an igloo. Igloos, in Army terminology, were low concrete buildings of semicylindrical shape, covered with sod. The arching walls were designed to direct the force of an explosion upward.[31] Several small igloos were already in existence at Edgewood Arsenal, including some half-dozen built as part of the emergency period expansion program in 1940–41.

When the incendiary bomb program materialzed, the CWS at once began work on plans for igloo construction at the proposed new depots on a scale large enough to provide permanent storage for 40,000,000 four-pound bombs.[32] A type of igloo used by Ordnance for the storage of smokeless powder became the prototype for the CWS building program. This igloo had exterior dimensions approximating 29 feet by 82 feet—twice the length of the igloos recently erected at Edgewood. According to estimates, it would store about 58,500 four-pound incendiary bombs in its 2,200 square feet of interior space. A 300-foot interval between igloos was considered standard.[33]

The new depots provided sites for hundreds of igloos. Two hundred and twenty went up at Midwest Depot, and some three hundred and fifty at Gulf Depot. Deseret accommodated 140 igloos. The activation of Northeast Depot in 1944 brought an additional fifty-eight igloos into the CWS storage program, so that altogether nearly eight hundred of these specialized magazines were brought into use by the CWS after completion of its original expansion plan at Edgewood.[34]

By the summer of 1942 the first shipments of incendiary bomb clusters were beginning to fill the new facilities. As the carloads arrived, the 100-pound clusters were manhandled into the igloos from the railroad docks via trucks and roller conveyors and stacked inside by hand, as many as twelve to a stack. This procedure, time consuming and laborious as it was, remained without much change for more than a year until the use of fork-lift trucks and pallets became general. A number of devices had by then been improvised for handling 100-pound and 500-pound clusters.

[11] Mrs. Lida Mayo and Dr. Harry C. Thomson. The Ordnance Department: Production and Distribution, a volume in preparation for the series UNITED STATES ARMY IN WORLD WAR II.

[12] See above, p. 342.

[33] Memo, C Supply Div OC CWS for C CWS, 30 Sep 41, sub: Fire Protection of Magnesium Incendiary Bombs in Storage. CWS 314.7 Storage File.

[34] (1) History of Midwest CWD, p. 6. (2) History of Huntsville Arsenal, 1941–45, p. 22. (3) History of Deseret CWD, p. 103. (4) History of Northeast CWD, p. 7.

Crane operated booms and jigs lifted a truckload of clusters at a single operation, the standard load being seven 500-pound M17 clusters.[35]

The igloo capacity of the CWS, despite its great expansion, was not enough to guarantee interior storage of bombs at all times. Frequently depots and arsenals found themselves obliged to resort to open storage. Furthermore, when supplies were moving quickly in and out of the depot, open storage was often the more economical of time and labor. Storage out of doors was not harmful if the necessary precautions were taken. The packaged clusters had to be placed on platforms allowing at least a few inches of air to circulate between them and the ground. Reasonable limits had to be observed in the size of the stacks, their nearness to each other, and the total number of clusters kept in one area.[36] Of particular importance was the necessity for providing the stacked clusters with some protection from the elements. At first, it was customary to cover the stacks with tarpaulins. It was not sufficient, however, simply to drape the weatherproofing on the stacks. While the packaged clusters were not very susceptible to damage from occasional incidental sprinkling, they were, on the other hand, vulnerable to corrosion and rotting if the tarpaulins covered them so closely as to prevent the free passage of air.[37] Some storage areas arranged stacks with a narrow row of boxes on top to provide a sort of ridgepole for the tarpaulin covering. Others used supporting frames of light timber. Midwest Depot, which found tarpaulins difficult to procure in quantity, hard to handle, and quick to deteriorate, devised a new system. The light timber "A" frames which had been constructed to support the tarpaulins were discarded. In their place 20 foot by 20 foot frames were built, covered with tarpaper, and placed on top of the stacks like so much shed roofing.[38] This proved to be adequate protection and not too burdensome to handle, provided cranes were available.

Bleach

The packaging and storage of bleaching powder was hardly as big a responsibility as the handling of incendiaries, but it proved to be one of

[35] (1) History of Midwest CWD, pp. 57–59, 66. (2) U.S. Army Photographs, Midwest CWD, 17 Aug 44 and 3 Nov 44. CWS 314.7 Storage File.

[36] Ltr, CO NYCWPD to C CWS, attn: C Supply Br Operations Div, 19 May 43, sub: Storage of M69 Incendiary Bombs at Loading Plants. CWS 400.24–NYCWPD–1943.

[37] Ltr, C Insp Div OC CWS to C Insp O NYCWPD, 5 May 44, sub: Storage of Finished M17 Aimable Clusters. CWS 400.24–NYCWPD–1944.

[38] History of Midwest CWD, pp. 77–78.

the most troublesome episodes in the wartime storage experience of the CWS. Bleaching powder (calcium hypochlorite), in addition to its powerful oxidizing action, liberates free chlorine. Since it was a cheap and abundant commercial item it was an obvious choice for chemical decontamination of the persistent toxic agents, which decomposed into relatively harmless compounds when chlorinated. On the basis of World War I experience, the CWS considered bleaching powder its standard general-purpose decontaminating agent, and once the nation was at war again it prepared to lay in large supplies.

No sooner had the depots begun to fill their warehouses with drums of bleaching powder than difficulties began to appear. The bleach was not high-test hypochlorite, a product of relative purity and stability, but a lower commercial grade of variable composition and inconvenient characteristics. It came packed in large steel drums, covered, but not tightly sealed. The powder took up moisture from the air and began evolving chlorine, sometimes at a rate sufficient to blow the tops off the drums. At the same time it was slowly but steadily corroding its containers, not only from the inside, but, thanks to careless packing and the resultant dusting of bleach on the drum exteriors, from the outside as well. This double process of decomposition and corrosion was accompanied by a parallel decline in the potency of the bleach itself. By the time the country entered its second year of war much of the bleaching powder held in storage by the CWS had become worthless.[39]

The situation had not failed to arouse concern. The CWS sought the advice of its suppliers at a conference at Niagara Falls in November, 1942. But the manufacturers could not offer much comfort. They themselves had never found an economical container for bleach more effective than the galvanized steel drum. Furthermore, it had never been customary in industry to keep bleaching powder in storage for more than a few months. After this meeting Lt. Col. Ludlow King, Chief of Inspection Branch, Industrial Division, OC CWS, was detailed to study possible substitute containers and came to the conclusion that no available metal drum could be regarded as offering guaranteed satisfaction for the long-term storage of ordinary American bleach. The CWS then adopted the practice of packaging bleach for storage in steel drums which had been provided with heavy coats of baked lacquer, inside and out. Containers of this sort

[39] (1) Ltr, C R&D Dept OC CWS to CO, CW Depot, Edgewood, 10 Sep 42, sub: Reclamation of Bleaching Powder. CWS 470.6/2751. (2) Baum, Brophy, and Hemleben, Storage and Maintenance, p. 730.

appeared to be the best available for the purpose, though they, too, were not immune from corrosion.[40]

In addition to improving the containers, CWS technicians could attack the problem of storing bleach successfully through improving the bleach. In early 1943 there seemed no immediate likelihood of procuring high-test hypochlorite from American sources for CWS use.[41] Fortunately another source of relatively stable bleaching powder was at hand. The British had been producing a surplus of bleach of a quality well above that of the American commercial grade, and from the fall of 1942 substantial quantities of this product were made available to the CWS through reverse lend-lease. Between September 1942 and March 1943 a total of nearly 16,000 tons of British bleach entered the CWS supply system, twice the amount obtained from American manufacturers in the same period.[42] But this windfall was not without its disadvantages. The British bleach arrived packed in drums which did not meet demonstrated storage requirements. The CWS promptly repackaged it in 100-pound lacquered steel drums. The job of repackaging was one of the most laborious experienced by the depots. The bleaching powder, as just noted, was corrosive and the chlorine gas it evolved was both suffocating and poisonous. The crews engaged in shoveling the bleach from container to container were obliged to wear full protective equipment, including gas masks and special clothing. They were greatly relieved when the task was done.[43]

Packing and Packaging

The problems encountered in keeping bleach in storage constituted only one instance of a general deficiency. Items had entered the distribution system before techniques had been developed to keep them in storage safely or see them on their way with reasonable assurance of safe arrival. One of the obvious responsibilities of a distribution system is to get matériel to its destination intact. To a large degree the successful fulfillment of this responsibility depends on the protection provided by the packing methods utilized. This fact is especially true when the system

[40] (1) Memo, Lt Col Ludlow King for C Field Requirements Br, Opns Div, OC CWS, 25 Feb 43, sub: Deterioration of Chloride of Lime Drums. CWS 314.7 Storage File. (2) Interv, Hist Off with Maj Eugene Lennon, Cml C, 27 May 58. (3) Interv, Hist Off with W. C. Gibbons, J. F. McGinty, R. J. Milano, and B. W. Redmerski, 10 Jun 58. These men all served in CWS Chemical Commodity Div in World War II.

[41] King memo, 25 Feb 43.

[42] CWS Report of Production, 1 Jan 40 through 31 Dec 45.

[43] (1) History of Midwest CWD, p. 70. (2) History of Eastern CWD, p. 95.

must supply expeditionary forces through all the hazards of wartime communications and in virtually all the climates of the world. The demands of the war on the CWS packaging techniques revealed shortcomings that had escaped notice during the peacetime years and the prewar build-up. It took many months for CWS packing doctrine and practice to catch up to the requirements of global war.[44]

For the most part, CWS packing and packaging had met ordinary peacetime standards. Packaging specifications were often simply references to ICC requirements for shippers using common carriers. Many items were never considered liable to overseas shipment and were packed in a manner suitable to the needs of domestic railroad requirements only, while even material bound overseas was given only the care and safeguards of normal peacetime ports and shipping. In some cases packing specifications which in themselves might have been basically sound were waived for shipments designated "emergency." The shortcomings of the existing packaging practices became generally apparent after the first major overseas landing operation by American forces in French North Africa late in 1942. Under the pressure of rough and hasty handling, improvised storage, over-the-beach landing, salt water corrosion, emergency unpacking, and the like, all factors inevitably associated with supply in an active theater of operations, many CWS packing and packaging methods failed to meet the demands made of them. This was true of Army packing in general, and theater complaints became the subject of top level Army concern.[45]

CWS officials, studying the reports of packaging failures and corrosion overseas, found six major factors responsible for the trouble: (1) inadequate packing and packaging design particularly in the selection of packing materials; (2) poor workmanship by inexperienced labor; (3) insufficient emphasis by inspectors on adherence to packaging standards; (4) poorly designed blocking and bracing, in view of the rough handling to be expected; (5) unanticipated outdoor storage; (6) unanticipated climatic conditions.[46] It was evident that immediate action was needed to redesign inadequate packages and packing to meet the actual stresses encountered.

[44] (1) Maj F. B. Shaw, Jr., "Crating, Packing and Marking" (a lecture before the Inspection School, Edgewood Arsenal), 15 Sep 43. CWS 314.7 Storage File. Major Shaw, a CWS reserve officer, directed CWS packaging research. (2) Pritchard, Birdsell, and Kleber, Chemicals in Combat.

[45] Chester Wardlow, *The Transportation Corps: Movements, Training and Supply,* UNITED STATES ARMY IN WORLD WAR II (Washington, 1956), p. 392.

[46] Abstract of Chemical Corps Packaging Activity During World War II, a study prepared by CmlC Tech Command (F. B. Shaw), Oct 46. See Ltr, CO Tech Command to C R&D Div, Liaison Group, same sub, 24 Oct 46. CWS 314.7 Storage File.

A packaging unit was created within the Technical Division early in 1943 and assigned specialized personnel and laboratory space at Edgewood Arsenal. This unit, subsequently raised to branch status, began at once to develop new designs and specifications where the need existed.[47] The basic problems dealt generally with increasing the strength of packages, cutting size and weight down as far as practicable, denying access to water or water vapor, inhibiting corrosion, and preventing mildew. Such things as materials shortages had to be kept in mind as well as the matter of ease and speed of packaging. The variety of overseas destinations multiplied the difficulties. The Pacific theaters, though the first impact of their requirements seems to have been less than that of the North African landings, presented some of the most complex problems. Supplies there were often landed on small beaches, without mechanical equipment or trained labor, and, in the early days especially, under the fire of enemy snipers or aircraft. Sometimes matériel was simply floated ashore. Once landed, it had to be hauled through jungles, stored during tropical rainstorms, and protected somehow from the corrosive humidity.[48]

The point of departure for packaging development in the CWS, as in the other branches of the Army, was War Department Specification 100-14A, which prescribed general requirements and indicated standard methods of crating and boxing. Within these limits, whenever possible, and outside them when necessary, the CWS packaging laboratory developed specific packaging requirements for all the items in the CWS supply system.

Crates were used for packing a few comparatively bulky CWS items, such as smoke tanks and smoke generators. These had to be specially designed in each case, with particular care to make sure that hard surfaced points on the item or the bracing were not so placed as to abrade the waterproof paper liner. Corrosion prevention for hardware was accomplished by cleaning all ferrous surfaces and coating them with grease or oil.

For the greater number of CWS items, boxes of one sort or another were devised and specified. In some cases the specifications were changed over and over again in the attempt to attain the best possible protection in the face of a variety of hazards. The 500-pound aimable cluster, M19, an adapter holding thirty-eight M69 incendiary bombs, was one such ex-

[47] (1) M. A. Raun and T. A. Treglia, "Packaging Development in the Chemical Corps." (2) Shaw Study CmlC Packaging Activity. Both in CWS 314.7 Storage File.

[48] S. J. Hemleben, History of CWS Activities at Ports of Embarkation (MS Monograph), pp. 134-35.

ample. The bombs had to be kept moistureproof, particularly since their fuzes contained black powder and would become inactivated if subjected to high humidity. There was no point in using vaporproof film covering with silica-gel dehydrator, as prescribed for moistureproof packing in some other services, because there was almost no silica-gel available to the CWS, nor could handlers conveniently or economically wrap the awkwardly shaped cluster in film without puncturing it. The first solution arrived at was a metal-sheathed, hermetically sealed plywood box. This proved satisfactory on an experimental basis, but attempts to secure rapid quantity production failed. Then a similar box made entirely of steel was substituted; it was unduly heavy but otherwise almost as satisfactory as the first. Again, production fell, in this case as a result of failure to observe the close tolerances needed to assure a vaporproof seal. By this time, however, a double steel drum pack (two steel drums fitted end to end over the cluster and sealed with a clamp and a sponge rubber gasket) had been worked out and proved to meet the basic requirements. This pack was ultimately adopted as standard. Subsequent difficulties ensued when stocks of fully dried wood for interior bracing ran out. To avoid raising the humidity inside the pack, a new bracing system was worked out incorporating moisture laden wood. This problem was solved only as the war ended.[49]

While troubles of this sort kept the packaging laboratory busy throughout the war, the worst of the lag in packaging development was overcome in the course of 1943. Before the year was out the packaging development chief was able to venture the opinion that most of the big changes had already been made.[50] But many routine packaging and packing designs remained to be worked out and revised during the remaining two years of war. Generally speaking, the problem of safely containing bulk quantities of highly reactive chemicals under wartime conditions was never solved. There was no certainty that existing containers for toxics would not burst or corrode, and the ever-present possibility of "leakers" in lots of toxic-filled drums or munitions imposed a perpetual state of alert on depot and transportation personnel. Even so familiar a commercial item as bleaching powder developed problems of corrosion in storage, mentioned earlier in this chapter, which were ameliorated but

[49] F. B. Shaw, Jr., "Packing Incendiary Bomb Clusters," *Armed Forces Chemical Journal,* III (April 1950), 20–21, 40.

[50] Shaw, "Crating, Packing and Marking."

DRUMS OF BLEACHING POWDER *stacked at a depot in England, August 1943.*

never completely solved before hostilities ceased, remaining to challenge the ingenuity of CWS technicians in the years that followed.

Distribution

The CWS distribution system functioned in general along lines laid down by the ASF. Its depots were allocated responsibilities by OC CWS in such a way as to conform with Army requirements for regional decentralization. For the most part its filler depots were located well back of the seaboard—in Utah, Arkansas, and northern Alabama, for example—a circumstance which tended to reduce congestion at and near the ports, as far as CWS matériel was concerned. The one major exception was Eastern Depot at Edgewood, Md., the original center of the distribution system; but the policy of moving storage functions back from the crowded coast was applied at Eastern also, when first the major part of its general supplies responsibility and then a substantial share of its ammunition storage functions were shifted inland to New Cumberland and Northeast Depots respectively. The CWS, which for years before the war had a minimal distribution load centering on a single depot consisting mostly of gas masks, succeeded in getting a nationwide depot system into operation,

meeting modern standards of depot management and materials handling, shipping large quantities of ammuntion and toxics without serious incident, and keeping supplies moving to overseas theaters, Lend-Lease nations, and the training centers at home.

Supplying the Corps Areas

During the emergency period before the entry of the United States into the war, the CWS, like the other supply services, supplied equipment to zone of interior installations and units through the several Corps Area commanders.[51] As in the period before the emergency each Corps Area Headquarters received requisitions from posts under its jurisdiction, edited them, and forwarded them to the appropriate supply service. CWS matériel was supplied by OC CWS through the depot at Edgewood. The first expansion of the peacetime distribution system centered in Edgewood Arsenal came early in 1941 when the Boston Chemical Warfare Procurement District was designated as the source of supply for training masks for posts in the First, Second, Third, and Ninth Corps Areas, and the Chicago District became the source for the remaining areas.[52] (At this period training masks for the suddenly expanded Army were the chief distribution responsibility of the CWS.) The new CWS depots and the chemical sections of the ASF depots did not begin to figure in the active distribution system until the end of the emergency period.

A few weeks after Pearl Harbor the War Department moved to expedite the distribution process by ending the role of the Corps Area Headquarters as a middleman between posts and depots. Henceforth, depots were to receive consolidated requisitions directly from post supply officers and make shipment accordingly.[53] By this time the chemical sections of the general depots were ready to bear their share of the distribution load. Accordingly, a new regional supply system was set up by OC CWS, giving Edgewood Depot responsibility for serving Corps Areas I–III, the chemical section of Atlanta General Depot responsibility for Corps Area IV, the chemical section of Memphis General Depot responsibility for Corps Areas V–VII, the chemical section of San Antonio General Depot responsibility for Corps Area VIII, and the chemical section of

[51] Ltr, TAG to CofS, *et al.*, 30 Dec 40, sub: Current Supply Policies and Procedure. AG 475 (12–27–40) M–D–M.

[52] (1) Ltr, OC CWS to Exec O Chicago CW Warehouse, 16 Jan 41. (2) Ltr, OC CWS to Exec O Boston CWPD, same date. Both in CWS 400.22/65.

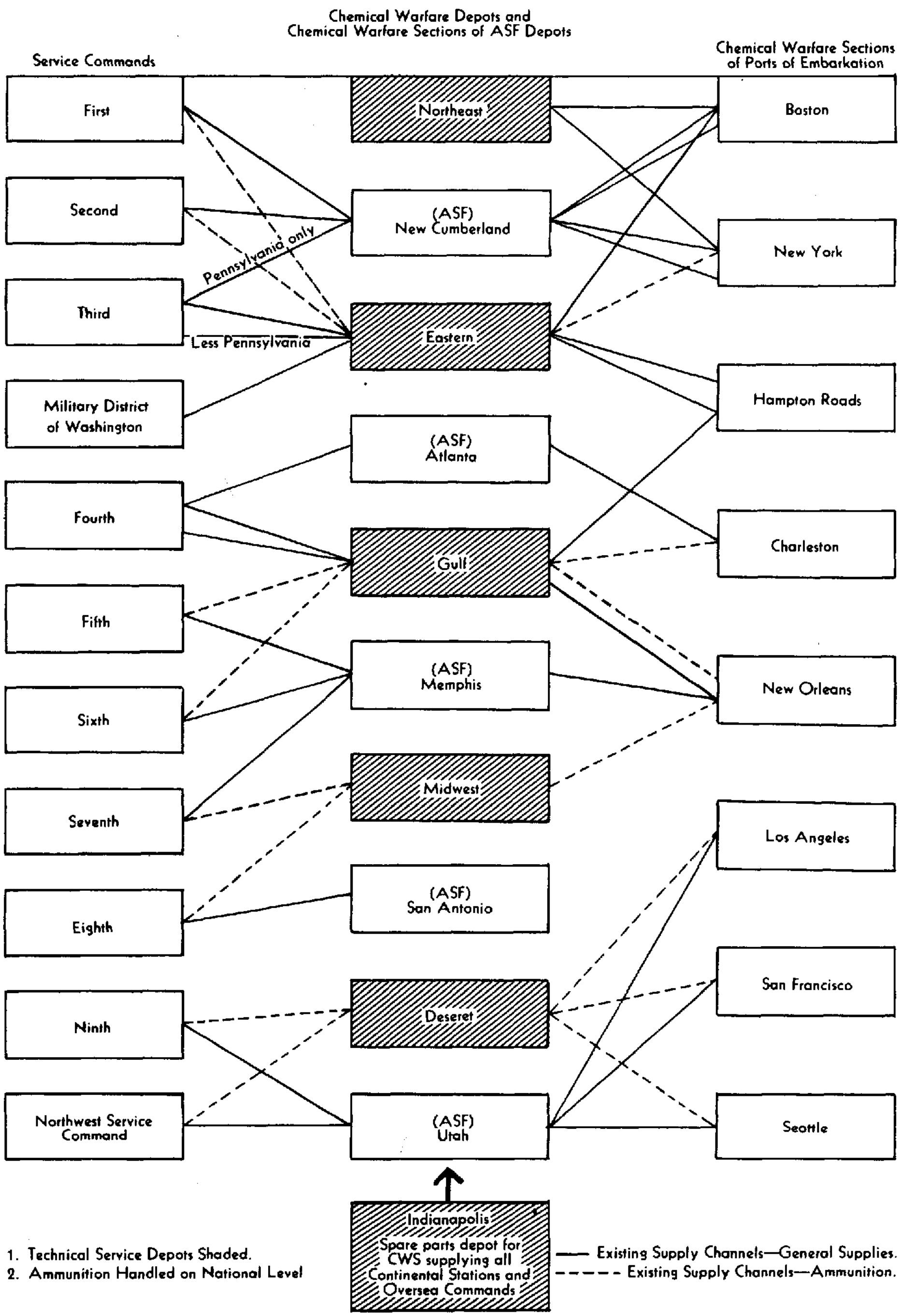
[53] Ltr, TAG to Chiefs Supply Arms and Services, 20 Jan 42. AG 475 (1–16–42)MO–D–M.

Utah General Depot responsibility for Corps Area IX. These chemicals supply points were required to maintain computations of unit allowances and records of current status of CWS matériel authorized for organizations in the Corps Area served.[54] This regional distribution system for general supplies was the first and basic step in CWS participation in the War Department's continuing campaign to decentralize supply functions and maintain balance in movement of matériel. World War I experience in the clogging of supply lines at the Ports of Embarkation provided a warning of the vital necessity of balancing supply movements with supply facilities, an example reinforced by the threat of congestion at east coast ports in 1942. The CWS regional distribution plan described above was limited to general supplies, such as protective equipment, and still left Edgewood with a disproportionately large share of responsibility. The system approached completion before the year was out, though, as one by one the new CWS branch depots were activated. Each of these became responsible not only for general supplies but also for the distribution of ammunition and toxics on a regional basis. Thus Gulf Depot dealt with the Fourth, Fifth, and Sixth Corps Areas (or Service Commands, as they were subsequently designated), Midwest with the Seventh and Eighth, and Deseret with the Ninth. The remaining Service Commands, the First, Second, and Third, continued to draw on Eastern Depot at Edgewood for the chemical ammunition. Eastern's supply load was further reduced on 30 April 1943 when its responsibility for the distribution of general supplies was cut back to that area of the Third Service Command south of Pennsylvania. The First and Second Service Commands, plus Pennsylvania, were served thereafter by an additional chemical section, that of the New Cumberland ASF Depot. Again in 1944 Eastern's storage and shipping load was divided when the activation of Northeast Depot (on a site originally developed by the Ordnance Department) provided an additional East Coast depot for chemical ammunition, a facility particularly helpful in providing extra back-up storage for the New York Port of Embarkation. (See Chart 2 for CWS distribution network.)

The regional allocation of responsibilities among the facilities in the CWS depot system served to meet ASF requirements for decentralized supply. The designation of depots by function—filler, reserve, distribution, or key—was also accomplished in accordance with ASF standards, though

[54] (1) Ltr, OC CWS to CmlO's Corps Areas *et al.*, 7 Feb 42, sub: Direct System of Supply for Posts, Camps and Stations. CWS 475/234. (2) S. J. Hemleben and E. M. Loughery, Distribution, vol. 4, pt. 5, in monograph series History of the CWS in World War II, pp. 821–23.

CHART 2—SCHEMATIC DIAGRAM, CHEMICAL WARFARE SUPPLY, AS OF 6 DECEMBER 1944



Source: Baltimore-Liaison Office, Storage Branch, Supply Division, OC CWS, Dec. 1944.

in an organization as small as the CWS, this required the assignment of multiple missions to most of the installations. Distribution depots were those which supplied matériel to posts, camps, and stations within a designated region. The chemical sections of ASF depots and the CWS branch depots fulfilled this function for general supplies and ammunition respectively. Reserve depots stored additional stocks for the replenishment of the distribution depots; this function was also included in the missions of all CWS storage installations, with a range of matériel, broad or limited as the case might be, specified in each instance. Filler depots provided a storage service for the Ports of Embarkation by filling Port requisitions out of their stocks, thus reducing the likelihood of an unmanageable accumulation of goods on the seaboards. Each CWS installation had a mission assignment as a filler depot for one or more ports. Key depots were those which stocked special items whose distribution could be more usefully accomplished from centralized control points than through the standard regional setup. The only CWS depot with this type of mission was Indianapolis, which controlled the distribution of all CWS spare parts.

An additional measure of specialization was carried out by the major CWS branch depots. Eastern, Gulf, and Midwest Depots shared locations with three of the four CWS arsenals. They took advantage of this circumstance to act whenever practicable as primary destinations for the products of their respective arsenals regardless of the ultimate destination envisaged. This tended to reduce crosshauling and backhauling by keeping the matériel out of any actual transit until it was needed. In order to perform the same service for Rocky Mountain Arsenal, which had no CWS depot at hand, Deseret established a storage area under its own jurisdiction adjacent to the arsenal.

Stock Control

A major purpose of the decentralizing of depot functions was, as has been stated, the avoidance as far as possible of the inevitable tendency to choke the lines of distribution with an oversupply of goods, a condition particularly acute at the ports, where the lines of distribution converged on a few overcrowded centers. A rigorous system of stock control, based on limitation of station stock levels and the provision of careful controls on the rate at which matériel moved to the ports was the obvious corollary of the new depot system. In 1942 the Control Division, ASF, made a survey of stock control practices in the CWS. The survey disclosed that a records system for approximately 1,000 items, including components,

was maintained. Of this number only thirty-eight were fast moving items, and on these a daily report was received from each depot and port of embarkation. This report which listed on-hand figures, was used as a basis for filling requisitions and setting up credits. On another sixty items weekly reports were made to the Office of the Chief, and on still another sixty-five, monthly reports were made. The remaining chemical warfare items were reported periodically. A record of all chemical warfare items in CW depots was maintained on hand-posted sheets in the OC CWS, as well as on a prescribed hand-posted form in the depots. The survey found that the system was workable only because there were few items and because the bulk moved slowly.[55]

Early in 1943 the Assistant Chief of Staff, ASF, for Operations, Maj. Gen. LeRoy Lutes, requested the chiefs of the various technical services to submit recommendations for implementing a stock control system.[56] During the next two months the ASF worked up a tentative stock control manual which was issued on 3 May 1943.[57] This manual was to be later revised several times on the basis of actual experience.[58] When issuing the tentative stock control manual, Headquarters, ASF, at the same time directed the technical services to set up stock control, storage, and maintenance units in their headquarters.[59]

The tentative stock control manual stipulated that the new system was to go into effect by 1 June 1943. It provided that each post, camp, and station as of that date would have an established supply level based on the actual needs of troop units. This level in most cases was first established as a 90-day level, a figure which fluctuated from time to time. All stocks above the established level were to be declared excess and returned to the depots. Stock levels were also established for the depots. Much co-operation was necessary among the commanding officers of the headquarters of the technical services, the headquarters of the service commands, the depots, and the post supply officers in order to fix accurate stock levels, but this objective was gradually accomplished.[60]

[55] The ASF survey is discussed in ICAF, R 116, History of Stock Control Army Service Forces, United States Army, Jan 48, p. 59. ICAF Library.

[56] Memo, ACofS for Opns SOS for C CWS, *et al.*, 11 Jan 43. Copy in ICAF R 116, Jan 48, p. 253.

[57] TM 38-220, 3 May 43.

[58] Revisions of TM 38-220, 9 May 44 and 10 May 45.

[59] Brophy and Fisher, *Organizing for War*, ch. VI.

[60] (1) Memo, Dir of Opns ASF for Chiefs of Tech Services, 13 Jul 43, sub: Depot Stock Levels. Copy in ICAF R 116, Jan 48. (2) *Logistics in World War II*, Final Report of the Army Service Forces, p. 80.

An important feature of the new stock control system was the scheduled requisitioning of supplies. Troop units sent their requisitions to the post supply officer who in turn presented his requisitions to the depot on a standard form and according to a fixed schedule. This innovation helped to prevent alternate periods of peak and slack activity in the depots. Station supply officers kept the chiefs of the technical services informed on the stock status of their particular stations and in that way the volume of stock to be maintained at the depots was gauged.[61]

Though the stock control system led to marked improvement in the issue of items, a serious deficiency in the distribution system still remained. That deficiency was failure to control the flow of materials from production lines to the depots. "That," said General Lutes after the close of World War II, "is an excellent illustration of one of the most important lessons about Army supply; that is, that the supply process is an individual entity and cannot be broken down into unco-ordinated phases such as production, stock control, and distribution."[62] With the advent of the supply control system in the Army in the spring of 1944 came a concerted effort to co-ordinate the various phases of the supply process.[63]

Lend-Lease

While the Chemical Warfare Service's program for supplying U.S. forces was moving into high gear, a parallel supply effort was already under way. The inclusion of the defense needs of friendly nations among the supply responsibilities of the Army antedated Pearl Harbor by more than a year and was given statutory authority by the Lend-Lease Act of March 1941. That portion of the War Department's lend-lease commitments represented by chemicals and chemical warfare supplies fell to the CWS to fulfill. The task of receiving and satisfying the demands of U.S. allies for such matériel was supervised by the Navy and International Aid Branch of OC CWS, but the main burden fell upon the regular staff and operating organizations in CWS.[64] The official beginning of CWS participation in lend-lease dated from shortly after the Lend-Lease Act was passed,

[61] ASF Annual Report for Fiscal Year 1943, p. 105.

[62] ICAF lecture, Lt Gen LeRoy Lutes, The Army Supply Program, 5 Feb 46, ICAF L 46-23, p. 7. In ICAF Library.

[63] See ch. XIII above for fuller discussion of the Supply Control System.

[64] The Chemical Warfare Service and International Aid (a monograph prepared by Hist Br OC CWS in Jun 44), pp. 3-4. MS in Hist Off. The first appearance of a lend-lease staff agency in OC CWS came with the creation of a Lend-Lease Division on 26 Aug 41 (OC CWS Off O 16, 26 Aug 41), renamed Defense Aid Division as of 24 Nov 41 (OC CWS Off O 39, 24 Nov 41).

but CWS concern with the war requirements of the British Empire went back somewhat farther than that. Though it was not called upon for foreign aid matériel in 1940, as was the Ordnance Department,[65] the CWS at this time did have very close liaison with the British Purchasing Commission, particularly on the procurement of chemicals. The official in charge of the procurement of chemicals on the British Purchasing Commission (BPC) was an American CWS reserve officer in the New York Chemical Warfare Procurement District, Lt. Col. W. Hepburn Chamberlain. Colonel Chamberlain's acquaintance with British requirements for chemicals enabled him to gauge the extent of the demands which would be made on American chemical resources under similar conditions, and the more he studied the matter the more he became convinced that the United States estimates were much too low. In 1940 Chamberlain left the BPC to join the Office of Production Management, where he was instrumental in impressing upon the leaders of the American chemical industry, with whom he was well acquainted, the need for expansion to meet wartime needs. In processing orders for the British (and that included the entire British Empire and its allies) he negotiated with the leaders of the American chemical industry on the expansion of existing plants or the building of new ones. These plants were a distinct asset to the nation once it got into the war.[66] Colonel Chamberlain was called to active duty as an Army colonel shortly after Pearl Harbor and became the officer in charge of lend-lease operations in the CWS throughout the greater part of the war.

The first direct impact of the Lend-Lease Act on the CWS came in April 1941, when the Secretary of War directed the transfer of 200,000 service masks, complete with spare canisters and repair kits, to Great Britain, for ultimate transshipment to Yugoslavia. The Chicago Procurement District's storage warehouse filled the order.[67] During the same month the first British requisitions for phosgene arrived.[68] In the course of the next few months the British requisitioned a number of defensive

[65] (1) Green, Thomson, and Roots, *Planning Munitions for War*, p. 73. (2) Levin H. Campbell, Jr., *The Industry-Ordnance Team* (New York: McGraw-Hill, 1946) p. 314.

[66] Interv, Hist Off with Col W. Hepburn Chamberlain, 3 Aug 54.

[67] (1) Memo, SW for C CWS, 9 Apr 41, sub: Transfer of Defense Articles to the United Kingdom (Lend-Lease Act). (2) Ltr, C CWS to CO Edgewood CW Depot, 7 Apr 41, sub: Preparation for Shipment of 200,000 Canisters . . . . (3) TT, Supply Div OC CWS to C CWPD, 7 Apr 41, sub: Shipment of Gas Masks. All in CWS 400.22/25.

[68] Form I, Requisition of Defense Articles under the Lend-Lease Act of March 11, 1941, dated 14 Apr 41 from U.K. (C. W. Reid, Chief, Requirements Office, BPC) to OPM. CWS 400.12/17.

chemical warfare items and chemicals.[69] More significant in terms of the future were the preparations under way late in 1941 for the first transfers to the British of incendiary bombs, destined to be the largest single item of lend-lease matériel handled by the CWS.[70] As early as October 1941, the Lend-Lease Administrator allocated $10,000,000 to the Army for construction of an incendiary bomb plant at Pine Bluff.[71] Planners thus fully realized that during the following year the major effort in the early production of incendiary bombs by the CWS would be for British requisitions, despite the fact that the United States entered the war in December. Though the CWS, in the absence of any directive to the contrary from higher authority, filled American requisitions for magnesium incendiaries before authorizing manufacture for British requirements, roughly two-thirds of the production of magnesium incendiaries (M50) went to fill British requirements. This two to one ratio was observed faithfully enough to give the WPB the impression that it had been based on a formal Anglo-American agreement.[72] The first lend-lease shipment of incendiary bombs was sent to Great Britain early in 1942. Before the war was over, a total of over 66,000,000 of the 4-pound magnesium bombs, M50, valued at more than $172,000,000 had been shipped to England, as well as 15,000 1000-pound aimable clusters, and a few M69 oil (napalm) incendiaries.[73]

Of the chemical agents that the CWS procured for the British, by far the most important was white phosphorus. Shortly after the United States entered the war the British were looking forward to an ultimate supply of a thousand tons of white phosphorus per month from the CWS. The total they actually received during the course of the war exceeded 16,000 tons.[74] The chief obstacle was not so much the production of the agent itself as the difficulty of getting it shipped. A critical shortage of con-

[69] Memo, C Supply Div OC CWS for ACofS G-4, 7 Dec 41. CWS 400.12/47.

[70] Memo, C Tech Svc OC CWS for C Defense Aid Div, 27 Nov 41, sub: Lend-Lease Report. CWS 400.12/169.

[71] Ltr, E. R. Stettinius, Jr., Lend-Lease Admin, to SW, 21 Oct 41. Production Div, ASF 471.6–Bombs, 1941–42.

[72] (1) Ltr, F. Eberstadt WPB to ACofS for Materiel SOS, 10 Dec 42. Production Div, ASF, 471.6–Bombs . . . . (2) Memo, Dir International Div for ACofS for Materiel SOS 14 Dec 42, sub: 4-Pound Incendiary Bombs. Production Div, ASF, 471.6–Bombs . . . .

[73] Lend-Lease Transfers, Chemical Warfare Service, May 46, Prepared by Sup and Dist Div, OC CWS. CWS 314.7 Lend-Lease File.

[74] (1) Memo, C Industrial Service OC CWS for Dir Defense Aid, 1 Apr 42, sub: Cml Items on the Fifth Supplemental with inclosure. Production Div, ASF, 470.6–U.K. (2) Lend-Lease Shipments, World War II, 31 Dec 46, p. 1. Prepared by Off C of Finance, WD.

tainers early in 1943 produced a proposal for a 70 percent cut in British allocations of white phosphorus. This evoked an immediate protest from the British supply mission. It called attention to the fact that the Combined Raw Materials Board had suggested that vital shipping space would be saved if the United Kingdom stopped importing American phosphate rock to make its own phosphorus and depended instead on getting the finished product from America. One of the two British phosphorus plants had already been closed down in consequence, and closure of the other was imminent. The shortage of shipping space being more serious than the shortage of steel for containers, the British view prevailed, and most of the cut in the white phosphorus allocation was restored.[75]

Of the other standard chemical agents, substantial quantities of phosgene and FM (titanium tetrachloride, used as a filling for smoke shells) went to Great Britain under lend-lease action. But the shipments of industrial chemicals which the CWS procured for British needs were often of greater importance than these. For example, a total of 34,000 tons of ethylene glycol, an engine coolant and antifreeze, was shipped to the United Kingdom during the war. Two special purpose rubber substitutes, neoprene and polyvinyl chloride, accounted for shipments of 7,500 tons and 8,500 tons respectively. It would take the enumeration of over fifty other chemicals to complete the list. Also of importance in the British lend-lease program were CWS-supplied smoke grenades, HC smoke mixture, and a number of items of protective equipment.[76]

The principal customer for CWS lend-lease shipment, after Great Britain, was the U.S.S.R. But unlike the British program, which was dominated by the mass production and shipment of incendiary bombs, the Russian requisitions were mainly for industrial chemicals. Chief among these, in terms of tonnage shipped, were methanol (28,000 tons), caustic soda (22,500 tons), phenol (18,000 tons), and ethylene glycol (13,000 tons). The only munitions which the CWS shipped to the U.S.S.R. in quantity were smoke pots. The Russians received about 1,300,000 M1 smoke pots (HC), and 130,000 floating smoke pots.[77] The heavy tonnage of caustic soda reflects in part the U.S.S.R.'s strong demand for this chemical, for use in refining petroleum. The requisition came after the Germans had retreated from the Caucasus at the start of 1943 and the

[75] (1) Ltr, Col G. W. Smythe International Div WD to British Ministry of Supply Mission, attn: Mr. C. W. Reid, 16 Feb 43. (2) Ltr, C. W. Reid Dir Requirements Br Min of Supply to Col G. W. Smythe, 20 Feb 43, with 1st and 2nd Inds. Both in Production Div, ASF, 470.6–U.K.

[76] Lend-Lease Shipments, World War II, pp. 1–16.

[77] *Ibid.*

Russian refineries had begun to receive once again the products of the Caucasian oil fields. After an all-out effort by CWS officials to locate every available source and organize immediate delivery, fifty-six carloads of caustic soda were assembled in Chicago and sent on their way. Somewhat later in the war, procurement of caustic soda was transferred from the War Department to the Treasury Department. Other chemicals sent to the U.S.S.R. by the CWS went into the manufacture of such military necessities as smokeless powder, plastics, explosives, and high octane gasoline.[78]

Certain shipping problems present to some extent in lend-lease distribution generally tended to become more acute in the case of the Russian supply program. Chief of these was the problem of co-ordinating shipments with vessels. Before 1942 was out, large stocks of some chemicals were being held in warehouses and War Department holding and reconsignment points because ships were not available to take them overseas.[79] It became evident eventually that the Russians were putting off acceptance of requisitioned chemicals for shipment whenever they had cargoes of greater concern to them ready to fill the available ships. In some instances these delayed chemicals were finally diverted to American war production, as in the case of 900 tons of unused sodium bromide.[80] For the most part, the CWS had to meet the storage problem as best it could. Special care had to be given to keeping containers in good condition during periods of unscheduled storage. On one occasion an inspection team from the Chemical Commodity Division, OC CWS, finding it necessary to perform an emergency repaint job on large lots of chemical containers held at Cheyenne, Wyo., had to call on Quartermaster troops for help in order to prevent further large-scale deterioration.[81]

Canada, Australia, French North Africa, China, and Brazil also received substantial amounts of CWS-procured matériel, though Canadian shipments were purchases, rather than lend-lease. The CWS sent to Canada some 3,500 tons of mustard gas and smaller amounts of lewisite, phosgene, and smoke mixture (FS), together with 400 tons of whetlerite and

[78] The CWS and International Aid, pp. 16–18.

[79] Ltr, Lt Col W. H. Chamberlain, C International Br OC CWS, to CG SOS attn: Col G. Olmstead, International Div, 28 Nov 42, sub: Deliveries of Lend-Lease Chemicals Held up by the Shipping Situation. Production Div ASF 470.6–Chemicals.

[80] Ltr, W. H. Healey WPB to Hq ASF, attn: Capt Baugh, International Aid Div, 17 Jul 43, sub: PD–1A Application . . . . Sodium Bromide . . . . Production Div, ASF 470.6–U.K.

[81] (1) Memo, Dir International Aid Div ASF for C CWS, attn: Col Chamberlain, 20 Aug 43, sub: Inspection of Lend-Lease Chemicals in Storage. Production Div, ASF 470.6–Chemicals. (2) Gibbons-McGinty-Milano-Redmerski interv, 10 Jun 58.

several hundred smoke generators.[82] Australia, preparing for the possibility of invasion after Pearl Harbor, felt it advisable to stockpile 4,000,000 civilian gas masks. As only a quarter of these could be produced locally, over 3,000,000 were requisitioned and obtained from the United States.[83] The CWS participated in the task of rearming the French by shipping to North Africa all the chemical warfare items for initial equipment and maintenance for the eleven French divisions being outfitted there in 1943. Service gas masks and dust respirators were the major items in this program.[84] The CWS also contributed its share to the limited flow of American supplies to China, via the China-Burma-India Theater. For the most part the CWS matériel sent to China consisted of weapons and ammunition, some of it for use in conjunction with General Stilwell's campaigns in Burma. Among the major items were 327 4.2-inch mortars, 1,470 portable flame throwers (for which the demand was increasing in the CBI Theater), over 500,000 mortar shells, and over a quarter of a million smoke grenades. Half a million outlet valve assemblies went overseas to keep the Chinese gas mask factories going.[85] Brazil received as lend-lease matériel the chemical warfare equipment needed to outfit the troops it sent to Europe early in 1944. Over and above these items, the CWS sent about 500 tons of bleaching powder to Brazil.[86] Small amounts of CWS matériel went as lend-lease to more than a dozen other countries. The final CWS report listed a total of 312 separate items procured for lend-lease.[87]

Supplying the Ports of Embarkation

A basic responsibility of zone of interior distribution was supplying the ports of embarkation, the Army commands which, under the general authority of the Chief of Transportation, supervised the transfer of men and matériel overseas. Within each of these commands a chemical officer served as adviser to the commanding general on technical matters in his

[82] Lend-Lease Transfers, CWS, May 46.

[83] Ltr, Australian Military Mission to Brig Gen H. S. Aurand, WD, 15 Jul 42, sub: Australia-Civilian Gas Respirators. Production Div, ASF 470.72–Australia.

[84] The CWS and International Aid, pp. 19–20.

[85] (1) Ltr, Lt Col E. O. Straw, Rear Echelon Hq USA Forces CBI to Dir International Aid Div, 17 Mar 44, sub: Flame Thrower Requirements. Production Div ASF 470.71–China. (2) Memo, Maj E. S. Hays for International Div ASF, attn: Maj H. Biggs, 18 Apr 44, sub: Items Requisitioned for Chinese Arsenal No. 23. Production Div ASF 470.72–China. (3) Lend-Lease Shipments, World War II, pp. 1–16.

[86] (1) The CWS and International Aid, p. 23. (2) Lend-Lease Shipments, World War II, pp. 1–16.

[87] Lend-Lease Transfers, CWS, May 46.

field while at the same time heading an organization performing a variety of CWS functions. The port chemical officer had a training mission, giving refresher training in protection against toxic gas to station personnel and troops bound overseas as well as decontamination training to help avoid accidents in handling toxic cargoes. He had an inspection mission, involving the checking of CWS cargoes for serviceability, safety, and proper loading and stowing. Finally he had a supply mission which required him to act as CWS supply officer at his post, forwarding requisitions from the theaters, filling shortages for units in transit, receiving, storing, and preparing for export CWS matériel received, and maintaining stock control records accordingly.[88] This supply function enabled the post chemical officers to serve as the link between the CWS distribution system and the ports, as represented by the commanding generals of the ports of embarkation and their staff sections. For the chemical officers were responsible in the first instance to the port commanders, rather than to the Chief of the CWS, and their activities in the field of overseas supply were carried on under the immediate direction of the ports' overseas supply officers.[89] Indeed, as far as the overseas theaters were concerned, CWS supply liaison was maintained through the overseas supply divisions of the ports, the agencies which first edited their requisitions, and hence only indirectly with the port chemical officers.[90]

Chemical sections were first activated in the ports of embarkation in the latter part of the emergency period. A chemical section existed in the San Francisco General Depot (which acted as supply agency for the San Francisco Port before Pearl Harbor) as early as October 1940, but the first Port Chemical Warfare Sections, properly so called, were those activated at the New York and New Orleans Ports of Embarkation in August 1941. Within three months after Pearl Harbor, CWS sections were in operation at the Seattle, Charleston, and Boston Ports of Embarkation, as well as at San Francisco, where the supply functions were shifted to the Port of Embarkation in December 1941. The Chemical Warfare Section of the Hampton Roads Port of Embarkation came into being in August 1942, and that month also saw the beginning of CWS supply functions at the Los Angeles subport, an installation which attained independent POE status in the fall of 1943. The volume of CWS lend-lease cargo passing

[88] Hemleben, CWS Activities at Ports of Embarkation, pp. 1–10.

[89] Chester Wardlow, *The Transportation Corps: Responsibilities, Organization, and Operations.* UNITED STATES ARMY IN WORLD WAR II (Washington, 1951), pp. 105–06.

[90] For a discussion of problems which arose in this area see Pritchard, Birdsell, and Kleber, Chemicals in Combat, ch. II.

through the Portland, Ore., subport necessitated the appointment of a port chemical officer there in September 1942. A final addition to the number of port chemical officers was made in December 1943 when a CWS officer was assigned to the Baltimore Cargo Port of Embarkation.[91]

As in the case of the service commands, the ports of embarkation operated under a regional allocation of CWS supply facilities. According to the pattern that ultimately emerged, the west coast ports dealt with Deseret and Utah Depots for CWS ammunition and general supplies respectively. Midwest and Memphis Depots served New Orleans Port of Embarkation similarly, with additional supplies shipped from Gulf Depot. The east coast ports were served by Eastern, Gulf, and Northeast CWS Depots and the ASF Depots at New Cumberland and Atlanta. The depots dealt with port requisitions directly and on a priority basis, advising OC CWS of shipments made. The CWS made periodic efforts to speed up the processing of requisitions which could not be filled at once from stocks on hand. In 1944, the chief's office received permission from Headquarters, ASF, to short-cut prescribed procedures by acting itself to teletype an order to a second depot to fill shortages in a requisition which the original depot could not complete. This system served to make OC CWS a clearinghouse for the speedier dispatch of unfilled extracts of requisition to known sources of supply and ended the necessity of having depots send them haphazardly from one to another until supply could be made. It also eliminated the additional delay involved in the earlier practice of routing the final shipping order back to the original depot before shipment was made to the ultimate supplier.[92]

By and large, the supply function of the chemical sections of the ports was an extension of the work of the depots. The tasks of storing, maintaining, shipping, and receiving were similar, as were many of the problems encountered. The sections had to devote time to checking the adequacy of packing and marking, replacing corroded containers, and maintaining surveillance over toxics. As the system of regional filler depots was elaborated by the ASF and the supply services, the ports of embarkation were enabled to close out a substantial share of their storage operations, but some necessarily remained to be performed on the spot.

The scale of operations varied considerably from port to port. The San Francisco Port of Embarkation, bearing primary responsibility for supply of the Pacific theaters, processed a rising flood of CWS equipment and

[91] Hemleben, CWS Activities at Ports of Embarkation, pp. 13–110.

[92] *Ibid*, pp. 123–24.

matériel, the monthly total reaching a peak of 63,287 measurement tons in July 1945, just as the war was being won. Incendiary bombs, grenades, napalm, mortar shells, toxics, and gas masks dominated the shipments.[93] The New York Port of Embarkation, which received the requisitions of the European and Mediterranean theaters, shipped its peak load of CWS matériel in April 1944, just before the Normandy landings, when 48,109 measurement tons were processed.[94] The other ports never dealt with burdens of this magnitude, but many of them had special needs to satisfy. The New Orleans Port of Embarkation, for example, shipped the variegated and often highly dangerous supplies needed for support of the San José research project in the Canal Zone. The Seattle Port of Embarkation experienced an emergency period during the Japanese invasion of the Aleutians in mid-1942, when men and supplies had to be gotten to bases in Alaska as rapidly as possible. The danger of submarine attacks in the early days of the war was such that some ports had to handle shipments diverted from more hazardous routes; the Los Angeles Port of Embarkation more than once had to ship organizational equipment to the China-Burma-India Theater for units whose personnel were shipping out by way of Charleston. This responsibility involved cross-country liaison through a representative of the unit concerned.

Generally speaking, the pace of the American war effort in the zone of interior tended to slacken in the summer of 1945, when only the conquest of Japan remained to be achieved. But the CWS experienced an opposite trend. The possibility of an all-out struggle in the Japanese home islands gave increasing significance to the chemicals, incendiaries, and smoke in the CWS arsenal and kept the rate of CWS distribution high. It was at this point, as noted above, that the CWS workload at the west coast ports rose to its peak. Then in August came the sudden surrender and the end of hostilities. The CWS effort, like that of the rest of the armed forces, made a full about turn. The storage and distribution network that had grown in four years from a single small depot to a system embracing ten major storage installations and as many port of embarkation sections, prepared to face the new responsibilities of demobilization.

[93] *Ibid*, pp. 166–74.
[94] *Ibid*, p. 224.

CHAPTER XVII

Industrial Demobilization

Preparations for Demobilization

As early as the spring of 1943 the Commanding General, ASF, at the direction of the Chief of Staff began to plan for demobilization. At that time, General Somervell set up a Special Planning Division in his headquarters to supervise demobilization planning. Because this type of planning was of vital concern to all major commands, the War Department in July 1943 transferred the Special Planning Division, whose chief was Brig. Gen. W. F. Tompkins, to the War Department General Staff.[1] There it remained throughout the war.

After the transfer of the Special Planning Division, the Commanding General, ASF, set up a Special Committee on Materiel Demobilization Planning, headed by Brig. Gen. Theron D. Weaver, who later became Director of Demobilization, ASF. It was at the suggestion of General Weaver's committee that the Chief, CWS, late in 1943, set up a Demobilization Planning Branch in the Control Division of his office. This branch was headed throughout the war by Col. Paul Sherrick. The Chief, CWS, appointed liaison officers on demobilization planning in the Industrial, Supply, Technical, and Field Requirements Divisions of his office and at the CWS installations. Because facilities loomed large in all CWS demobilization plans, he set up a separate demobilization unit in the Facilities and Requirements Branch, Industrial Division, OC CWS, in 1944.[2]

[1] (1) Logistics in World War II, Final Report of the Army Service Forces, pp. 214–15. (2) Memo, Dir Special Planning Div WDGS for CWS, 30 Jul 43, sub: Demobilization Planning. CWS 314.7 Demobilization Planning File.

[2] (1)Memo, Brig Gen Theron D. Weaver, Chairman, Special Committee on Materiel Demobil-

Demobilization planning fell into two general categories, the computation of special demobilization Army Supply Programs and the drawing up of specific plans for such activities as disposition of facilities, contract terminations, and property disposal. Both types of planning were carried on under a formula which provided for two separate periods of demobilization—Period I running from V-E Day to V-J Day and Period II for six months after the defeat of Japan. The Demobilization Planning Branch, OC CWS, was responsible for co-ordinating the compilation of the special Army Supply Programs, while the demobilization unit in the Industrial Division of the chief's office and demobilization officers in the installation drew up plans for disposition of facilities, contract termination, and disposal of surplus property.

Demobilization planning got under way in the procurement districts following an indoctrination course in the chief's office in January 1944. Selected senior officers from the districts attended this course, which covered the main aspects of demobilization. After returning to their home stations these officers were put in charge of demobilization planning activities for their respective districts. In April 1944 Readjustment Divisions were activated in all procurement districts to administer demobilization planning, contract termination, and property disposal. These divisions not only planned future contract termination and property disposal actions but also supervised current activities along those lines in the districts. Demobilization planning officers were also appointed in the arsenals, but their duties were confined chiefly to planning the disposition of CWS facilities.

On 27 October 1943 the ASF directed the technical services to submit by 20 December 1943, at least in skeleton form, plans for partial demobilization in Period I.[3] Headquarters, ASF, furnished a guide in the form of a control chart listing operations considered necessary to accomplish demobilization objectives. These operations included the disposition of industrial facilities, the curtailment of industrial construction, and the disposition of supplies. After submitting the skeleton the CWS added flesh

ization Planning, ASF, for C CWS, attn: Mr H. C. Walsh *et al.*, 27 Oct 43, sub: Project Control Charts for Materiel Demobilization Planning. File SPUPE in folder, Chronology I, 2 Jul–28 Dec 43, Minutes Interdepartmental Group on Materiel Demobilization Planning, Dir of Industrial Demobilization ASF. (2) Brig Gen W. F. Tompkins' address before Army Industrial College, 5 Jan 44, entitled, War Department Demobilization Planning. CWS 314.7 Demobilization Planning File. (3) R. Stanley McCordock, Demobilization, 1 Apr 47, pp. 12–13, 20–21, in monograph series History of the CWS in World War II. (4) Activities of Control Division, OC CWS, 1 Jan 44 to 31 Dec 44.

[3] Memo, Brig Gen Theron D. Weaver for C CWS *et al.*, 27 Oct 43, sub: Project Control Charts for Materiel Demobilization Planning.

and the product became the Chemical Warfare Service Materiel Demobilization Plan, Period I—Echelon of the Office of the Chief. This document went through several editions, the final one appearing under the date of 20 May 1944.

The Materiel Demobilization Plan for Period I included a statement of the demobilization objectives of the CWS, a list of governing policies, and an assignment of responsibilities of each element of the chief's office in the period of demobilization. Objectives were listed as: (1) immediate termination of the maximum quantity of war production consistent with continuing requirements for the war with Japan and sound economic practice; (2) expeditious settlement of terminated contracts and prompt removal of government owned matériel and industrial equipment from plants of private contractors; (3) efficient disposition of excess Chemical Warfare Service property; and (4) retention in pilot production, standby or reserve, of such government owned facilities and equipment for the production of noncommercial items as might be necessary for continuing development of techniques and for the availability of adequate production capacity to insure future military security.[4]

The Materiel Demobilization Plan for Period I devoted ten pages to governing policies. These were listed under such headings as provision for gas warfare, research and development projects, restriction of contracts and purchase orders, and retention of arsenals and industrial facilities. As to gas warfare, the policy was promulgated that facilities would be disposed of only after due consideration of the possible initiation of that type of warfare. Planners decided that with the defeat of Germany all research and development projects would be reviewed to determine if they would be useful against Japan, if they could be completed within eighteen months, or if they were important as long-range developments. New contracts and purchase orders were not to be placed unless they were specifically found to be necessary for the defeat of Japan.

From the spring of 1944 until the spring of 1945 the chief's office worked on still another demobilization plan, the one for Redeployment, Readjustment and Demobilization, Period I. This plan, published on 1 March 1945, listed the same objectives as those contained in the previous 20 May 1944 plan on matériel demobilization, only in much more detail. It listed not only the actions that the chief's office would take in the demobilization period, but also those which the installations would take.

[4] CWS Materiel Demobilization Plan Period I for Echelon of Office of the Chief, 20 May 44, p. 1. CWS 314.7 Demobilization File.

Five weeks before the surrender of Germany, all responsible officers in OC CWS and at the installations received a copy of this plan.[5]

After the defeat of Germany the Demobilization Planning Branch began to give serious consideration to plans for Period II. The surrender of Japan and the end of hostilities, coming early as they did, found the plan still in its infancy. The CWS, therefore, continued to operate under the plan for Period I, most of the features of which applied with equal force to Period II.

Disposition of Facilities

On 6 October 1943 the Chief, Control Division, OC CWS, suggested to General Porter that decisions be made on the following questions: (1) which of the CWS arsenals would be retained as peacetime installations; (2) which existing facilities were to be expanded—by the addition of a gas mask factory, for example, or of a 4.2-inch chemical mortar and shell line; and (3) what other government owned facilities should be retained as war reserve.[6] The Chief, CWS, referred these questions to the commanding officers of the arsenals for study and reply.[7]

Among the policies laid down in the Materiel Demobilization Plan for Period I was that planners concerned with the matter should give due weight to the suitability of arsenals and plants for peacetime retention. Under the plan for Period I all four CWS arsenals were to be retained. Edgewood was to be the chief center for gas mask production and was also to be used for experimental and pilot-scale production of chemical agents, weapons, and defensive items. Huntsville's primary mission would be to produce smoke matériel and its secondary mission to turn out chemical agents. Pine Bluff would be engaged exclusively in producing incendiary munitions, while Rocky Mountain's primary mission would be the manufacture of chemical agents and weapons.

But facilities planning was not confined to a mere statement of policy. In line with the emphasis General Somervell was placing on the limitation of construction in 1944,[8] the technical services were directed to draw up detailed plans for demobilizing facilities. These plans sought to co-

[5] McCordock, Demobilization, p. 70.

[6] Ltr, C Control Div OC CWS, 6 Oct 43, sub: Demobilization Planning. Cited in McCordock, Demobilization, pp. 15–16.

[7] See Memo, CG RMA for C CWS, 13 Dec 43, sub: Demobilization Planning. CWS 370.01, RMA. McCordock, Demobilization, pp. 16–17.

[8] Jesse A. Remington and Lenore Fine, The Corps of Engineers: Construction in the United States, a volume in preparation for the series UNITED STATES ARMY IN WORLD WAR II, ch. XIV.

ordinate the requirements set forth in the Army Supply Program with the need for facilities. In September 1944 the CWS submitted its first facilities plan for Period I to the ASF, and in December a revised version.[9]

In 1945 the CWS began to pay an increasing amount of attention to plans for disposing of its facilities. In May the chief's office directed that all CWS arsenals be surveyed to determine measures needed to implement the policies on the arsenals laid down in the 20 May 1944 Materiel Demobilization Plan. The survey board, headed by Col. Harry W. Spraker, scrutinized each arsenal and made recommendations as to what plants should be retained or placed on a standby basis. It also estimated the expenditure required to make permanent improvements at the various plants. This estimate totaled just under $47,000,000.[10]

At a 12 July 1945 conference of key ASF and CWS officers a formula was drawn up for disposing of all CWS facilities at the close of hostilities. Under this formula facilities fell into three categories: Class A, those that would be retained; Class B, those that could not be classified at the time; and Class C, those that could be put up for advance sale. In addition to the four CWS arsenals, the following plants were listed as Class A: Marshall, St. Louis, Owl 4X, Seattle, Columbus, Kansas City, and New Cumberland. There was no listing under Class B plants. The list of Class C plants included ten government owned plants and five CWS sponsored plants.[11] In September the following plants were removed from the Class C category and placed in Class B: Midland, Lake Ontario Ordnance, Firelands, San Bernadino, and Turlock.

The Chief, CWS, advised the Commanding General, ASF, on 10 August, that the clothing renovating plants, which were operated by The Quartermaster General with CWS technical assistance, would continue to operate on a full time basis at the close of hostilities. The chlorine and mustard plants at Rocky Mountain and Pine Bluff Arsenals would continue on a reduced basis, as would the mustard plant at Edgewood. Fifty percent of the workers at the Edgewood Arsenal Machine Shop would be retained because they were doing work for the laboratories at the Chemical Warfare Center. Also scheduled for continued operation were the Vigo

[9] Activities of Control Division, OC CWS, 1 Jan 44–31 Dec 44, pp. 27–28.

[10] Report of Board on Permanent Construction at Installations Chosen for Post War Retention, 23 June 1945, *passim.* CWS 314.7 Demobilization File.

[11] The government owned plants were Firelands, San Bernadino, Turlock, Zanesville, Birmingham Smoke Mix, Birmingham Smoke Pot, Midland, Lake Ontario Ordnance, Niagara Falls, and Duck River. The CWS sponsored plants were operated by Lempco Products Co., Bell Aircraft Ordnance Division, Bell Machine, Ferro Enamel Corp., and Rheem Manufacturing Co.

Plant and the contract on the 4.2-inch chemical mortar shell at the Milwaukee Stamping Co. At certain other key industrial installations, according to plans, a cadre of 20 percent of the workers were to be kept to put equipment in standby condition. The following day, 11 August, the Chief, Industrial Division, directed the arsenals to cut back production of chemical agents and the procurement districts to end production of specified munitions.

At 1900 on 14 August the President officially announced the end of war. Within an hour General Porter's headquarters was sending out detailed instructions to the arsenals and districts on cutting back production schedules. The period of full-scale demobilization had begun, a period characterized by drastic reduction of military and civilian rolls and by concentration on such activities as property disposal, processing and packaging of chemical items for reserve storage, putting plants in standby condition, and contract terminations. The arsenals reduced the number of workers much more drastically than did the procurement districts; by the end of 1945 about 90 percent of arsenal civilians were released as compared with about 50 percent of district workers.[12] The procurement districts retained a larger percentage of their workers in order to carry out contract termination and property disposal activities.

Contract Terminations

As the war approached its end the CWS placed greater stress on terminating contracts. On 10 August the Chief, Industrial Division, OC CWS, directed the commanding officers of the procurement districts to prepare lists of all contracts to be terminated as well as books of telegrams on termination to be released to the Western Union the moment the war was over. This activity harkened back to a similar experience in World War I, when, as indicated, CWS contracts were terminated expeditiously.[13] But this action was an exception to the general situation in the War Department. When hostilities were suddenly concluded in November 1918 the government found that its authority to settle many contracts was dubious, that there was definite need for a sound organization to carry out settlements, and that in many instances no criteria whatsoever had been established for effecting settlements. More than 3,000

[12] These percentages are based on figures appearing in the histories of CWS installations in the period 15 Aug to 30 Dec 45.

[13] See ch. I above. The number of CWS contracts was comparatively small.

of the 30,000 contracts terminated were later appealed to the U.S. Court of Claims and this litigation dragged out over an average period of three and a half years per contract. In a word, World War I experience demonstrated the need for such procedures as a uniform termination article, a uniform termination policy, statutory authority to effect negotiated settlements, and confirmation of the government's right to carry out interim financing.[14]

During the emergency period preceding World War II, the War Department took its first significant step to improve contract settlement procedure when in October 1941 it made mandatory the inclusion of a termination article in all standard fixed-price contracts. It took a further step a year later when it introduced the principle of negotiated settlement into the termination process. A negotiated settlement represented a compromise between the claims and counterclaims of the government and the contractor with the aim of compensating the contractor equitably for the unfinished portion of his contract.[15]

The War Period

Termination of contracts was a factor in CWS procurement almost from its inception, but the first wave of terminations did not come until the M54 bomb program was cut back in the spring of 1942.[16] Since the War Department had not yet compiled guidelines on termination procedures, CWS contracting officers suddenly found themselves facing such problems as how to reimburse the contractor for his inventories of raw materials, for his commitments to his suppliers, and for his work in process. Some contractors were already losing money; should these men be allowed profit on a partially completed job when they would have suffered loss on a completed job? In an effort to formulate answers to such questions the procurement district offices worked out procedures on contract termination based on accepted principles of law and accounting, and at least one district, New York, put these procedures in writing. When difficulties of interpretation arose the district offices communicated with the legal branch of the chief's office for guidance. But not until

[14] (1) Smith, *The Army and Economic Mobilization,* ch. XXVII. (2) Jerry Maxfield, Industrial Mobilization Course: Termination of Contracts, 7 Jun 46, ICAF, L 46-96. ICAF Library.

[15] Smith, *The Army and Economic Mobilization,* pp. 620-21.

[16] The program was cut from 20,000,000 to 13,500,000 bombs. See Memo, C Ind Svc OC CWS for Chairman ANMB, 2 May 42, sub: Magnesium, and 1st Ind. CWS 400.17/12.

mid-1944 did the latter branch exert close supervision over termination activities throughout the CWS.[17]

From the summer of 1943 on, meanwhile, the War Department began concentrating on contract termination activities. In June a Contract Termination Branch was set up in the Purchases Division, ASF; in August a new termination section (PR 15) was added to War Department Procurement Regulations; and in November the Readjustment Division, ASF, was activated to deal with all matters relating to demobilization, including contract termination. Spurred on by both the Office of the Under Secretary of War and by Headquarters, ASF, the Chief, CWS, began to put greater emphasis on contract termination. Early in 1944, as indicated, he arranged for a course on contract termination and property disposal in his headquarters, and in April he directed that Readjustment Divisions be set up in the procurement districts. At the same time the Assistant Chief, CWS, for Materiel urged the commanding officers of the districts to keep in personal touch with contract termination matters and to provide for the training of future termination officers.[18]

The War Department was but one of six major procurement agencies in the government; consequently there was need for developing uniform termination procedures for all these agencies.[19] At the request of the President, Bernard Baruch and John Hancock made a study of contract settlement and property disposal matters, which they embodied in their Report on War and Post-War Adjustment Policies (15 February 1944). Congress was meanwhile studying the need for new legislation and passed the Contract Settlement Act of 1944.[20] This act, which pointed out the need for speed, equity, and finality in the settlement of terminated contracts, created an Office of Contract Settlement with a director empowered to prescribe policies, procedures, and standards on contract settlements.

[17] (1) Interv, Hist Off with John J. Geraghty, 10 Sep 58. Geraghty was the legal officer in charge of termination activities in the Atlanta CWPD and later (from Nov 44 to Apr 46) in the chief's office. (2) Interv, Hist Off with James M. Poyner, 10 Sep 58. Poyner was Chief of the Readjustment Div in the Dallas CWPD during World War II. (3) Ltr, Robert M. Estes to Hist Off, 18 Feb 58. Mr. Estes as a member of the Legal Branch of the New York CWPD worked on the terminations of M54 bomb contracts in 1942. A copy of the procedures compiled by the Legal Branch of the NYCWPD in the spring of 1943 is in CWS 314.7 Contract Termination File.

[18] (1) Ltr, Asst C CWS for Materiel to all CWS Proc Dists, 10 Apr 44, sub: Readjustment Activities. (2) Ltr, Asst C CWS for Materiel to CO's of Arsenals and Proc Dists, 1 Jul 44, sub: Training for Contract Termination. Both in CWS 161.

[19] Others were the Navy, the Treasury Dept, the Maritime Commission, RFC subsidiaries, and the Foreign Economic Administration.

[20] 58 *Stat* 651, approved 1 Jul 44.

The summer of 1944 saw more emphasis in the War Department on contract termination than ever before.[21] After the passage of the Contract Settlement Act, Headquarters, ASF, urged the technical services to pay as much attention as possible to advance planning of termination settlements and to assist contractors in becoming familiar with the termination articles in their contracts. The services were to advise contractors to form termination sections in their organizations and to train personnel in operations involving the prompt settlement of claims and disposal of inventories. In the CWS the chiefs of the readjustment divisions in the procurement districts arranged one-day courses for contractors in the principal cities of the districts. The ASF also directed the technical services to obtain written termination plans for certain contractors.[22] In August 1944, for example, the CWS was directed to obtain such plans from three contractors.[23] With the issuance of the Joint Termination Regulations on 1 November termination officers were furnished an authentic guide for carrying out their duties.[24] As of late December 1944 the termination planning program in the CWS was rated as among the most advanced in the ASF.[25]

The procedures which the CWS followed on contract terminations generally resembled those followed throughout the Army.[26] At the procurement district level the chiefs of the readjustment divisions appointed "settlement teams" to carry out termination actions. Each team was headed by a negotiator, who was assisted by members qualified in property disposal, accounting, and engineering. The membership of a team remained unchanged only through the termination of a particular contract. Under the guidance of the negotiator the team took the necessary steps to effect settlement of the claim, complete plant clearance, and process the claim to final payment. In carrying out plant clearance the teams received invaluable assistance from the inspection offices of the procurement districts. Washington headquarters reviewed all termination actions in excess of $5,000. The Legal Branch reviewed all terminations for compliance with the

[21] Smith, *The Army and Economic Mobilization,* p. 613.

[22] (1) Memo, Dir Readj Div, ASF, for C CWS, 10 Aug 44, sub: Termination Planning. CWS 161. (2) ASF Circular 366, 6 Nov 44, pt. II.

[23] The contractors were Lempco Products, Inc., Monsanto Chemical Co., and Continental Can Co., Inc. See Ltr, Asst C CWS to CO's of all CWPD's, 12 Aug 44, sub: Termination Planning. CWS 161.

[24] Smith, *The Army and Economic Mobilization,* p. 629.

[25] Memo, Maj Thomas F. Parks for Col Curtis G. Pratt, 27 Dec 44, sub: Appraisal of Pretermination Program. ASF Readjustment Div 161, Pretermination Planning, 1 Nov 44–28 Feb 45.

[26] For a good account of general termination practices in the Army and Navy see Maxfield, Termination of Contracts, pp. 11–12.

Joint Termination Regulations and other directives while the Fiscal Division checked the accounting methods followed in the termination action. Representatives of the chief's office, moreover, reviewed all terminations of less than $5,000 on periodic visits to field installations.[27]

Postwar Activities

With V-J Day came an all-out effort to quickly terminate all war contracts. Both in the Washington headquarters and in the procurement district offices this objective became the first order of business. By August 1946 the CWS could report that there were only six contracts that had not yet been terminated.[28] Three of these were with Erie Basin Metal Products, Inc., and Batavia Metal Products, Inc. The other three were with Pressurelube, Inc.

While the settlement of CWS contracts in the postwar period was carried out with speed, there is, unfortunately, good reason to suspect that administration of various aspects of the settlements left something to be desired. In November 1946 the Chief, Chemical Corps, appointed a Contract Settlement Review Team to assist all contracting officers to properly document all termination actions. The basic purpose behind the appointment of the team was protection of the contracting officers and the corps as a whole.[29] Some of the disclosures brought about by the Senate committee investigating the Erie Basin and Batavia contracts had convinced the Chief, Chemical Corps, as well as his superiors in the War Department of the need for such a team. A civilian with considerable experience in Ordnance Department termination, Christian Van Heest, was selected to head the team. Van Heest was assisted by a group which varied in number from six to ten, several of whom had had previous termination experience in the Ordnance Department.[30]

Although the purpose behind its appointment did not include investigation of termination actions taken by contracting officers, the team could not help but draw certain conclusions relative to such actions.[31] Among

[27] (1) History of Dallas CWPD Aug 45–Apr 46, pp. 33–34. (2) Inspection Div, OC CWS, Policy Letter 21, on Contract Terminations, 25 Oct 44. CWS 161. (3) Memo, Dir Readj Div, ASF, for C CWS, 27 Jul 45, sub: Review of the Administration of Termination Settlements and 1st Ind, 31 Jul 45. CWS 161.

[28] Memo, Legal Br OC CWS for Supply and Procurement Div OC CWS, 28 Aug 46. CWS 161.

[29] Ltr, Deputy Chief, CmlC to CO's of CWPD's, 2 Dec 47, sub: Contract Termination Review Program. CWS 314.7 Contract Termination, Van Heest File.

[30] Interv, Hist Off with Christian Van Heest, 10 Jul 58.

[31] Ltr, Christian Van Heest to CCmlC, 27 Apr 49, sub: Report on the Administration of Contract Terminations by the Chemical Corps, with inclosed report. CWS 314.7 Contract Termination Van Heest File.

other observations, it expressed the conviction that the government regulations on contract terminations were well thought out. Errors of omission and commission were not the result of faulty regulations but rather of poor administration of the regulations. Under the stress of war the War Department had not placed sufficient emphasis on training future contract termination officers. Relatively few CWS officers, for example, had been given the opportunity to attend the excellent course in contract terminations given at the Army Industrial College in 1944. At the close of the war, in consequence, hundreds of inexperienced officers were placed in termination positions. "Surprisingly enough, however," the report says, "the majority of settlements made by the Chemical Corps appear to have been made with justice to the contractor and the government. It is with the minority that we are primarily concerned. While the number of termination settlements indicating excessive payments, or the use of questionable judgment, is comparatively small, the amounts involved are large and therefore a matter of concern in any future emergency."

Among specific criticisms of the report was the comment that although the accountants, both military and civilian, were very well trained and efficient they should have co-operated more closely with engineers and the other technical experts with regard to the value of inventories. The report did not hold the accountants responsible for the situation but blamed it on those administering the program.

The report is critical of the manner in which inventories were disposed of by the CWS. In many instances contractors' plants were cleared in thirty days instead of the allotted ninety days, a feat that would have been commendable had the action been properly carried out. Unfortunately, however, disposal officers often short-cut the regulations, with the result that the government acquired many items it later had to dispose of as scrap. The lack of documentation on disposition of inventories was very frustrating. In "hundreds of cases" the team was unable to find any evidence on the disposition of items.

Under provision of the Joint Termination Regulations, contract review boards were set up at the various CWS installations. In most instances these boards were entirely military and the officers who sat on them were of lower rank than the negotiating officer submitting the proposed settlement for review. "Ordinarily," the report states, "such a review board would not be likely to question the acts of a superior officer." The report recommended that in any future emergency the selection of members of

review boards be given closer attention; that at least two qualified civilians with business experience sit on each board and that no military member be below the rank of major.

In its final recommendation the report urged that contract terminations be studied in connection with the peacetime Industrial Mobilization Program, so that in any future emergency proper instruction might be given to prospective negotiators and property disposal officers.

The report of the Contract Settlement Review Team might have made several additional observations in its analysis of the situation in the CWS. One of the reasons for poor property records was that many CWS small contractors did not have facilities to set up necessary records when they undertook a contract. Later CWS termination offices had to attempt to reconstruct the property record back to the time the contract was awarded. The efficiency with which property records were administered, as well as with regard to other aspects of contract terminations, differed among CWS installations. Some had excellent staffs and closely supervised all aspects of termination activities; others did not have enough qualified people and operated in a rather haphazard manner.

At the root of the difficulty was the tendency to relegate contract termination activities to a secondary role while the war was in progress. Both at the chief's office and at the installations the first objective was considered to be the procurement and supply of chemical munitions to the armed forces; in the light of the expanding overall chemical warfare procurement program this tendency was natural. An indication of the relatively minor importance assigned to contract terminations is the delay in activating a Readjustment Division in the Washington headquarters; not until October 1945 was that division established. Had such a division been set up under a competent chief (preferably a man with about fifteen years experience in contracting) at the time the Readjustment Divisions were activated in the procurement districts in 1944, the supervision of all CWS contract termination activities would have been greatly improved.[32] As actually carried out, the supervision of various termination activities was divided among several elements of the chief's office. In addition to the overall supervision of termination actions by the Legal Branch, the Fiscal Division supervised property accountability and the Property Disposal Branch all matters relating to the disposal of surplus property.

[32] Geraghty and Poyner interviews.

Property Disposal

Half a dozen years after the close of World War I, the CWS was still disposing of surplus property.[33] With the passage of time additional materials, particularly chemicals, became surplus and these the CWS disposed of by transfer to other branches of the War Department or to civilian agencies.[34] In 1937 several of the deteriorated buildings at Edgewood Arsenal were sold as surplus.[35]

One effective means of speeding up production in the emergency period was through eliminating large reserves of outmoded property through prompt disposal.[36] The First War Powers Act of 18 December 1941 provided for the sale of serviceable property to war contractors without going through the formality of declaring it surplus. Supported by this provision of the act and by rulings of the War Production Board, the War Department in October 1942 issued Procurement Regulation Number 7 on disposing of surplus and obsolete property. Under this regulation the CWS as an element of the Army carried on its disposal activities during the first half of the war. If the service found it impossible to sell excess property to war contractors, it drew up a list of the material which it circulated among other supply services of the Army and among elements of the Navy. If another service wanted all or part of the material it was transferred; if not it was declared surplus and reported to the Procurement Division of the Treasury Department. If the Treasury Department did not indicate an interest the CWS sent out invitations to private industry to bid on the surplus property.[37]

The war period naturally witnessed the accumulation of a considerable amount of excess property by the CWS. Among the causes of this development was the elimination of certain munitions such as the M54 bomb and lewisite. When these programs were discontinued the items were declared surplus, and in the case of lewisite the plants also.[38] When a manufacturing program was eliminated the machinery in the plant gen-

[33] See ch. I above.

[34] Rpt of CWS, 1931, p. 23, and 1936, p. 4.

[35] *Ibid.*, 1937, p. 4.

[36] Memo, TAG for Chiefs of Supply Services, 23 Dec 42, sub: Surplus and Obsolete Property. ASF (SPX 400.7 (12-18-42) OB-P-SPDDS-MPR).

[37] 3d Ind, Asst C Ind Div OC CWS to CO Edgewood Arsenal, 3 Apr 43 on Ltr, CO Edgewood Arsenal to C CWS, 4 Feb 43, sub: Excess Property. CWS 400.7 EA 1943.

[38] In 1944 the CWS shipped considerable lewisite equipment from Rocky Mountain Arsenal to the Corps of Engineers Manhattan Projects. See Résumé of Activities, OC CWS, for Week Ending 16 Sep 44.

erally became surplus. Another cause for the accumulation of excess property was the practice of discarding old model items or old type matériel when a newer model or a newer type had been developed. Still another cause was the refusal of Russia to accept certain chemicals, particularly ammonium chloride, which the CWS had purchased and packed for lend-lease shipment.[39] Basic, of course, was the fact that gas warfare did not eventuate, with the result that the armed forces did not expend its gas warfare ammunition. Since most CWS matériel, moreover, was not suitable for civilian use, the service faced a more difficult problem of disposal than did other elements of the Army.

By the spring of 1943 the property disposal situation was becoming serious enough to warrant the appointment of special officers to administer the program. In April the Chief, CWS, in accordance with a directive from the ASF made the Chief of the Priorities and Allocation Branch, Industrial Division, in his headquarters, salvage and excess property officer in addition to his other duties. At the same time he directed the commanding officers of the installations to appoint property disposal officers. In May 1943 the ASF set up a Redistribution and Salvage Branch in its headquarters to supervise these activities in the technical services. The extent of CWS disposal activities by the end of 1943 is indicated by the value of sales and transfers of salvage and excess property for the last six months of 1943, which totaled $7,825,507.[40]

General English, Chief, Industrial Division, in General Porter's office did not believe that the service was putting forth its best efforts in disposing of surplus property and in December 1943 he urged the installations to become more active in this matter.[41] What was true of the CWS was evidently true of the ASF generally, for in the spring of 1944 General Somervell was quoted as saying that he "did not know of any situation in the Army Service Forces that was any worse than the disposal of surplus property."[42] One cause was the long period of time being consumed in disposing of inventory and industrial property, which was in turn leading to delays in contract settlements.[43]

There was a variety of reasons for the leisurely pace of industrial prop-

[39] Résumé of Activities, OC CWS, for Weeks Ending 8 Apr and 22 Apr 44.

[40] (1) OC CWS Adm O 7, 28 Apr 43. (2) OC CWS Organ Chart, 6 Mar 44 and 10 Aug 44. (3) Résumé of Activities, OC CWS, for Week Ending 15 Jun 44, Report of Industrial Division.

[41] Ltr, Brig Gen P. X. English, C Ind Div OC CWS, to CG EA, *et al.*, 6 Dec 43, sub: Redistribution and Salvage Program. CWS 314.7 Demobilization File.

[42] Min, Mtg ASF Staff Conference, 14 Mar 44, p. 13. Control Div, ASF Files.

[43] Min, Mtg ASF Staff Conference, 22 Feb 44, p. 3. Control Div, ASF Files.

erty disposal, but in the judgment of an officer who had a number of years experience in production one seemed predominant. Col. Louis W. Munchmeyer, who directed the program in the Office of the Chief, CWS, in an address to members of the Industrial Division in the fall of 1944, blamed it on the human frailty of the typical production man who wanted "to hide a piece of equipment" for possible use if a similar piece should break down.[44] That there was a great deal in what Colonel Munchmeyer said seems to be indicated by the fact that from early 1944 the ASF and other pertinent government agencies placed much emphasis on ferreting out industrial equipment that had been hidden away.

The Latter War Period

The Baruch-Hancock Report of February 1944 led to drastic reforms in the field of property disposal no less than in contract termination. The first result was establishment of a Surplus Property Administration in the Office of War Mobilization.[45] The Surplus Property Administration arranged for the Reconstruction Finance Corporation to act as a disposal agency in addition to the Procurement Division of the Treasury Department. The Reconstruction Finance Corporation handled general purpose equipment, machine tools, and chemicals, while the Procurement Division, Treasury Department, was restricted to consumer-type property.

Another important outcome of the Baruch-Hancock Report was the enactment of the Surplus Property Act of 3 October 1944.[46] This act created a Surplus Property Board of three members. Appointments to the new board were completed in January 1945 and the board's regulations were made available to the ASF in April. In September the board was abolished and a single administrator appointed.[47]

While the CWS conducted its surplus property functions under the general supervision of Headquarters, ASF, it also had direct contacts with the Surplus Property Board and later the Surplus Property Administration.[48] The Property Disposal Branch in the chief's office formulated pro-

[44] Remarks of Col L. W. Munchmeyer, Rpt of Ind Div Conf at OC CWS, 15–16 Sep 44, p. 63. CWS 314.7 Property Disposal File.

[45] E O 9425, 19 Feb 44.

[46] P.L. 457, 78th Cong.

[47] (1) Logistics in World War II, Final Report of the Army Service Forces, p. 224. (2) Herman M. Somers, *Presidential Agency* (Cambridge, 1950), p. 181. (3) Industrial Mobilization for War, vol. I, 724–26.

[48] On 1 October 1945 the Surplus Property Administration took over the functions of the Surplus Property Board. On 31 January 1946 the President under Executive Order 9689 transferred the functions of the Surplus Property Administrator to the Chairman of the Board of Directors of the War Assets Corporation. This same Executive Order provided that as of 25 March 1946 a War Assets Corporation be set up to handle all surplus property functions.

cedures for CWS disposal activities based on the regulations and directives of the War Department and the top level government disposal agencies.[49] These procedures were printed in a CWS Property Disposal Manual. The branch also carried on a training program for CWS property disposal workers through conferences and meetings, through correspondence, and through personal contacts.

It was the opinion of those who directed the wartime disposal program in the CWS that ASF administration of property disposal was of an excellent character. General Somervell's headquarters laid down clear-cut instructions aimed at redistributing property on an equitable basis, and although these instructions were not always palatable to individual commanders, they were beneficial to the CWS and to the Army as a whole. The handling of surplus property by the Reconstruction Finance Corporation was not looked upon with very much favor because of alleged delays of that agency in carrying out disposition.[50]

Among the most important of property disposal procedures was the compiling of complete descriptions of each individual item to be disposed of. It was not possible, for example, to sell a gas mask production line as such. Instead, a complete description of every item going into that line, such as motors and sewing machines, had to be made. After the description was drawn up it was circulated to likely military branches, such as the Ordnance Department or the Corps of Engineers. If these had no use for the item and it was less than $100 in value it could be sold to a war contractor. In September 1944 an innovation was introduced in that items for sale were disposed of through the service command, which had more facilities for effective sales. The items that were not sold were declared surplus to the Surplus Property Board and later the Surplus Property Administration.[51]

Major salvage projects in the CWS included the gas mask carrier and gas mask disassembly program and the protective ointment program. These projects got under way after General Porter received a letter from General Somervell late in 1944 stressing the critical manpower shortage and the

[49] WD publications of particular importance were TM 38-505, 24 Apr 44, and ASF Manual M419, 1 Aug 45.

[50] (1) Ltr, Col L. W. Munchmeyer to Hist Off, 26 Mar 52. (2) Ltr, Frederick H. Schovoir to Hist Off, 6 Mar 52. Mr. Schovoir was Property Officer at Edgewood Arsenal during World War II. (3) For evidence that criticism of RFC delays were not confined to CWS, see Lyle B. Brundage, Storage Operations December 1941-45, an unpublished history of Storage Division, ASF, p. 253.

[51] Remarks of Col L. W. Muchmeyer in Rpt of Ind Div Conf, OC CWS, 15-16 December 1944, pp. 61-68. CWS 314.7 Property Disposal File.

desirability of utilizing the labor of prisoners of war.[52] The gas mask program, which was carried on at some half dozen points throughout the country, resulted in the salvaging of webbing, hardware, and minor components badly needed by both the CWS and the Quartermaster Corps.[53] The protective ointment program consisted of the salvaging of approximately 27 million tubes of ointment which had been declared surplus to the War Department in early 1945.[54] The ointment was removed from the tubes and stored in drums and the tubes and various packaging material was transferred to other services of the Army and to the Navy.

In the period July 1943 through July 1945 the CWS made available for disposal property valued at $143,051,000. (*Table 10*) Of this amount property valued at $126,910,000 was actually disposed of during the period.[55]

TABLE 10—CWS PROPERTY DISPOSAL ACTIVITIES, JULY 1943 THROUGH JULY 1945 [a]

Type and Action	Amount
Available for Disposal Total	$143, 051, 000
Nonmilitary property	$85, 195, 000
Military property	37, 095, 000
Contractor-inventory (including contractor owned)	20, 761, 000
Disposals Total	$126, 910, 000
Transferred in CWS	$50, 289, 000
Transferred in salvage	33, 105, 000
Transferred to other War Department components and Navy	20, 655, 000
Sold	14, 001, 000
Transferred to SPB disposal agencies	8, 860, 000

[a] All figures in the tabulation are based on initial cost.

Source: Property Disposal Branch, OC CWS, compilation, CWS 314.7 Property Disposal File.

[52] Ltr, CG ASF to C CWS, 21 Dec 44. CWS 314.7 Demobilization File.

[53] Gas mask salvage projects were carried on at Camp Grant, Ill. (later transferred to Camp Ellis, Ill.); the CW warehouse in Chicago, Ill.; Camp McCoy, Wis.; Pine Camp, N.Y.; Camp White, Oreg.; and Ft. Devens, Mass.

[54] Ltr, AC Ind Div OC CWS to CG EA, 7 Feb 45, sub: Ointment, Protective, M4. CWS 400.24.

[55] ASF commended the C CWS for the "most outstanding manner" in which the CWS carried out its excess property mission. See Memo, Dir Readj Div ASF for C CWS, 6 Feb 45, sub: Redistribution of Excess Property. CWS 314.7 Property Disposal File.

The end of fighting in the Pacific saw an immediate increase in CWS property disposal activities, as the following figures indicate. The total volume of all types of property (contractor-inventory, nonmilitary, and inventory) for the period January-July 1945 amounted to $8,623,000; for the month of August 1945 alone the figure was $23,274,000. *Table 11* lists the original dollar value of all CWS property disposed of during the calendar year 1945.

TABLE 11—CWS PROPERTY AVAILABLE FOR DISPOSAL, JANUARY-DECEMBER 1945

Period	Total	Contractor-Inventory	Nonmilitary	Military
Total	$159,042,000	$54,572,000	$47,587,000	$56,883,000
January-July	8,623,000	255,000	3,905,000	4,463,000
August	23,274,000	936,000	7,186,000	15,152,000
September	31,044,000	15,078,000	9,883,000	6,083,000
October	41,700,000	18,995,000	8,171,000	14,534,000
November	35,282,000	15,342,000	15,386,000	4,554,000
December	19,119,000	3,966,000	3,056,000	12,097,000

Source: Rpt of Property Disposal Br, OC CWS, August-December 1945. CWS 314.7 Property Disposal File.

The Postwar Period

The War Department in the months immediately after the close of hostilities urged the technical services to "jar loose supplies of civilian-type items." [56] The CWS encountered little or no problem in disposing of matériel that had a civilian use. In addition to sales to private industry, the service disposed of a number of items by grants to schools and colleges through the U.S. Office of Education. These items included chemicals in small quantities, laboratory equipment, gas alarms, decontaminating apparatus, chemical mortar carts, 55-gallon drums, eyeshields, mechanical smoke generators, chemical agent detector kits, floating smoke pots, dust respirators, ¼-ton trailers, ¼-ton tractors, and impregnating plants.[57] But with the bulk of chemical warfare matériel it was different. After

[56] Remarks of Lt Gen LeRoy Lutes, CofS ASF, in Résumé of ASF Staff Conference, 28 Dec 45, p. 1. ASF Hist Files, National Archives.

[57] Ltr, C Property Disposal Section OC CmlC to CO's of all Chemical Corps Installations, 12 Nov 46, sub: Donation of Surplus Property under PR7-316. CWS 400.7, Jul-Dec 46.

setting aside certain quantities of munitions as war reserve, there were still vast quantities on hand.[58]

It was the matériel for which there was no civilian demand that created particular disposal problems. Such items as toxic agents, "goop," and certain raw chemicals had very little or no commercial value.[59] Shortly after the close of the war some toxic agents were dumped at sea, but the problem of disposing of surplus toxics was to persist for a number of years.[60] Some "goop" was eventually disposed of by turning it over to state government agencies in the far west and to certain lumber companies who used it to destroy undesirable brush.[61] Among the raw chemicals the CWS had difficulty in selling were ammonium chloride and arsenic trichloride. The former was used as a catalyst in the manufacture of lewisite and its chief commercial use was in preserving the greens on golf courses. But there were just not enough golf courses in the United States to absorb the quantity of ammonium chloride the CWS had on hand. Arsenic trichloride was also used in the production of lewisite, and after the CWS discontinued the manufacture of that agent in mid-1944 it declared 1,700,000 pounds of arsenic trichloride surplus to the Reconstruction Finance Corporation. By March 1946 less than 250,000 pounds had been sold and the remainder was in storage at Pine Bluff.[62] This situation pointed up a grave postwar problem facing the CWS: its depots and other storage facilities were bulging with items long since declared surplus.

Until early 1946 the CWS experienced little difficulty in administering its surplus property program. The procedure was for the service to notify the War Department periodically of the amount of surplus property on hand, but no great pressure was exerted to reduce these surpluses. In February 1946 War Department policy underwent a complete change.[63] The new policy called for the disposition of all items for which there was

[58] For data on the disposal levels of individual items see file CWS 400.7, Jan–Mar 46.

[59] "Goop" was an incendiary material produced by one of the CWS contractors. See ch. VIII above.

[60] The War Department would not approve sufficient funds for proper storage of toxic agents, but neither would it approve funds for disposing of toxics in appreciable quantities. Consequently the CWS "couldn't afford to keep [mustard and lewisite] or dispose of it." Comment of Maj Gen Alden H. Waitt, former Chief Chemical Officer, on margin of draft copy of this chapter, Sep 58.

[61] Interv, Hist Off with Lt Col Harold F. Zimmerman, 23 Jan 58. Col Zimmerman was in Property Disposal Br, OC CWS, during and following World War II.

[62] Ltr, C CWS to CG ASF, attn Maj William M. Teffingwell, Readj Div Distribution Br, 25 Mar 46, sub: Disposal of Surplus Chemicals and Kindred Items that Remain Unsold for a Twelve Month Period. CWS 400.7.

[63] WD Circulars 34, 5 Feb 46, and 38, 7 Feb 46.

not a definite military need.[64] Although this approach put a tremendous burden on the Property Disposal Branch of the chief's office as well as on the installations, it did bring about greater disposition of surplus material.[65]

The task of the CWS property disposal officials was not made any lighter by the unfavorable publicity which the service was receiving in 1946. In July a Senate committee began its open hearings into the Garsson contracts.[66] That same month some 33 leaking German mustard gas bombs were dumped into the Gulf of Mexico about 60 miles off the coast of Alabama in 100 fathoms of water. Despite all evidence to the contrary and despite the fact that similar phenomena had occurred periodically in various regions throughout the world, the death of some fish off the coast of Florida was blamed on this action.[67] In the fall of 1946 the service received more unfavorable publicity when some workmen suffered burns while unloading leaking shells from a munition ship at Mobile, Ala.[68] As a result of all this notoriety the CWS was anything but the darling of the War Department at the time. But this predicament was not without its compensations. Under the circumstances the Chief, CWS, insisted that his subordinates co-operate fully with higher headquarters and be most scrupulous in carrying out property disposal transactions. It stands to the credit of the CWS that, unlike some other elements of the Army, no serious question was ever raised by higher authority as to the propriety of the service's disposal actions.

To Be or Not To Be?

During the war the ASF not only assumed responsibility for supervising such technical service activities as disposition of facilities, contract termination, and property disposal; it also set up organizational and administrative standards for all elements under its jurisdiction, and General Somervell's headquarters did not confine its concern for Army organization to the war period, but made plans for the postwar period as well. As

[64] See OC CWS, Disposition of CWS Items, 10 Apr 46 and 15 Jul 46. CWS 400.7.

[65] Interv, Hist Off with Lt Col Robert A. Owendoff, 14 Jul 58. Colonel Owendoff headed the Property Disposal Br, OC CWS, in the postwar period.

[66] See ch. XV above.

[67] See MC OUT 44842, Kenneth C. Royall, SW, to Hon J. Hardin Peterson, Member of Congress, 15 Aug 47. CWS 314.7 Property Disposal File.

[68] See account of the decontamination of the *Francis L. Lee* in Guard and Security, pp. 45–47.

early as the summer of 1944 the Control Division, ASF, began working on such a plan. As finally evolved, this plan envisioned a setup consisting of a commanding general, ASF, assisted by a dozen staff officers, six of whom would also serve as chiefs of technical services. Each technical service would have functional rather than commodity responsibilities.[69] For example, the Quartermaster Corps would return to its traditional Army function of distributing all Army supplies, the Medical Department to medicine, the Engineers to engineering, and the Ordnance Department to procuring everything for the Army. As the wartime Chief of Control Division, ASF, later expressed it, "In such a shift, the Chemical Warfare Service simply gets lost." [70] Under the ASF plan the functions of the CWS were to be transferred to the Ordnance Department.

Somervell's recommendations were among those studied by a board of officers appointed by General George C. Marshall on 30 August 1945 to prepare a plan for the peacetime organization of the War Department.[71] In the course of its study this board, whose chairman was Lt. Gen. Alexander M. Patch, interviewed Under Secretary Patterson and Assistant Secretary Robert A. Lovett, and a number of high ranking officers, including Generals Eisenhower, McNarney, and Walter Bedell Smith. On 18 October the Patch board submitted its recommendation to the Chief of Staff. A new board, headed by Lt. Gen. William M. Simpson, was then appointed to consider suggested adjustments to the Patch board recommendations. On 28 December the Simpson board submitted its report, which differed in only minor details from the Patch board report.[72]

General Porter was one of the officers interviewed by the Patch board. When Porter appeared before the board on 13 September he carried in his hand a note he had received from Under Secretary Patterson two days before. This note was a reply to a 7 September letter from Porter to Patterson, written at the latter's request. This letter had listed arguments in favor of an independent chemical service. Patterson's note, which Porter read at the start of his testimony, included the following statements:

[69] Millett, *The Organization and Role of the Army Service Forces,* p. 422.

[70] Ltr, Clinton F. Robinson to Hist Off, 28 Apr 58. See also Ltr, John D. Millett to Hist Off, 19 Apr 58.

[71] Memo, Brig Gen H. I. Hodes, Asst DCofS, for Lt Gen Alexander M. Patch, Maj Gen H. A. Craig, Maj Gen H. C. Ingles, and Maj Gen P. E. Brown, 30 Aug 45, sub: Reorganization of the War Department, CofS file, Reorganization of War Department (Patch-Simpson Boards) 19 Aug 45.

[72] The Patch and Simpson Board reports, together with the testimony of the various persons interviewed, are in the CofS files marked Reorganization of War Department (Patch-Simpson Boards).

You make a strong case for the continuance of the Chemical Warfare Service. It is a convincing case so far as I am concerned. The record made by the Chemical Warfare Service has been a notable one. I know of no move to merge your service with any other service, having heard nothing more than casual talk on the subject.[73]

In Porter's 7 September letter to Patterson—wherein he made "the strong case for the continuance of the Chemical Warfare Service"—he indicated in the opening paragraph that about ten days before the two men had discussed the future of the CWS when they met on an airplane.[74] Porter at that time was cognizant of the plans of the ASF to combine the CWS with the Ordnance Department.[75] In the course of the conversation Patterson had asked the Chief, CWS, to send him something in writing justifying the continuance of a separate chemical service.

"First and foremost" among the reasons which Porter propounded was the need of an agency for co-ordinating chemical research, as well as biological and physical research. The CWS was the only War Department agency in existence prepared to carry out this mission. It would be very unwise, Porter felt, to subordinate such a vital activity to an element of the War Department already saddled with a huge supply and service mission. It would be particularly unfortunate in the light of the ever increasing importance of research and development to warfare.

The second reason which the Chief, CWS, presented was that since the application of research and development to warfare was relatively new, these activities should not be confined by the "shackles of existing weapons and channels of thought" nor should they be relegated to a secondary position in some technical service.

A distinction between the kind of research and development performed by the Ordnance Department and that carried out by the CWS constituted Porter's third point. Whereas Ordnance research, development, and procurement followed fairly well defined patterns, based essentially on commercial and industrial commodities, those of the CWS were largely noncommercial. Ordnance, moreover, had no concern whatever with medical or biological research.

Porter's "fourth vital point" was predicated on the proposition that selling new ideas was always a difficult task:

[73] Testimony of Maj Gen William N. Porter before Patch Board 13 Sep 45, in CofS files Reorganization of War Department (Patch-Simpson Boards). Copy of this note is also in CWS 300.4–1945.

[74] Ltr, C CWS to Robert P. Patterson, Under Secretary of War, 7 Sep 45, sub: Justification for an Independent Chemical Warfare Service. CWS 321 file marked Secretary of War 1945.

[75] Interv, Hist Off with Maj Gen William N. Porter, 30 Apr 57.

Absent a protagonistic approach [he stated], new ideas are often suppressed, or, at best, impeded and delayed. That the history of suppression is not theoretical is borne out by the history of the 4.2 mortar; this war would not have had the mortar—with its brilliant record—but for the advocacy of the Chemical Warfare Service. . . . I need not multiply incidents—you know the conflict within our own armed forces and those of our allies on high explosives versus incendiaries, and how effective a weapon incendiaries have proven to be, and how the development of smoke and flame has progressed only because of the singleness of interest of the Chemical Warfare Service.

These were Porter's four principal reasons for the continuation of the CWS. As he himself indicated, they centered around the research and development mission. To these four Porter added five additional reasons for a separate organization. These were that the CWS had a combat and field staff mission related to its research mission, that the size of the CWS was just about right for carrying the chemical and biological activities of the armed forces, that the storage and shipment of chemical munitions required special handling, that the CWS was unique in military circles in having experience in the production of defense as well as offensive munitions, and that if the CWS were eliminated it would not be feasible to simply transfer its activities to the Ordnance Department because certain of these activities were more akin to the missions of other elements of the Army, such as the Quartermaster Corps, the Medical Department, and the Corps of Engineers. Although General Porter did not point out the fact, distribution of responsibilities would have meant a reversion to the situation that had existed in World War I before the establishment of the CWS.

In his testimony before the Patch board, Porter, in answer to specific questions, went into more details on certain items, especially the biological warfare activities of the CWS. But essentially his arguments were those embodied in his letter to the Under Secretary of War.

The duties of the Chief, CWS, as defined in the National Defense Act included not only the development, procurement, and issue of smoke and incendiary materials and toxic agents, but also the organization, equipment, training, and operations of special gas troops, and such other duties as the President might from time to time prescribe. This list of duties indicates that the CWS was not only a service branch of the Army but also a fighting branch or arm in that it was responsible for the training of special troops and for their employment in battle.

The Chiefs of the Chemical Warfare Service never interpreted their role as being confined solely to development and procurement of matériel. They believed that the special weapons which the service developed and

procured should be tried out by special troops for whose training the CWS was responsible. Only on the basis of such experience, they felt, could sound training doctrine be formulated. General Porter, no less than his predecessors, was imbued with this concept; he saw the CWS as an organization with balanced and interacting responsibilities for research and development, supply, training, and combat employment of chemical munitions. For that reason it would have been inconceivable for General Porter to have subscribed to any such shifting of CWS responsibilities as the Army Service Forces suggested in 1945. That the General Staff was convinced of the validity of Porter's thesis seems obvious from its decision to maintain the organizational integrity of the Chemical Warfare Service.

APPENDIX A—STATUS OF CWS FACILITIES PROGRAM AS OF 30 JUNE 1945

Facility and Project	Authorized Amount	Date Authorized	Construction Started	Actual or Scheduled Initial Completion	Percent Completed 6–30–45	Actual or Estimated (E) Final Completion	Type of Contract
Grand Total	$352,891,174.95						
Government Owned and Operated, Total	310,657,270.30						
Edgewood Arsenal, Edgewood, Md., Total	39,028,044.41						
Rehabilitation Program	2,180,795.86	To 11–9–43	11–1–40	12–15–41	100	3–31–44	LS, FA
Rounding Out & Additions	22,596,322.93	To 12–14–44	9–18–40	10–15–41	99	10–1–45(E)	FF, LS, FA, SD
Eastern CW Depot	2,439,011.00	To 3–13–44	9–17–40	6–27–41	100	7–5–44	LS, FF
CWS School	914,643.00	To 12–30–43	10–15–40	12–1–41	100	5–31–44	LS, FF, FA
Office & Troop Facilities	6,005,799.00	To 5–25–44	12–1–40	6–1–41	100	9–16–43	LS, FF, FA
Medical Division	1,617,814.00	To 12–5–44	6–9–43	3–15–44	100	6–30–45	LS, FF
Technical Division	915,544.29	To 12–30–44	10–20–42	1–20–43	99	8–1–45(E)	LS, FF, FA, SD
Maintenance, Repairs & Alterations	401,534.96	To 12–14–44	7–1–40	9–15–40	95	7–31–45(E)	FA, SD
Prisoner of War Camp	22,507.00	To 11–16–44	8–20–44	9–28–44	100	4–3–45	LS
CG Fill. (Bldg. 84) WP Fill. (Bldg. 90) Mach. & Equip.	10,397.00	1–10–45	Data not available				SD
H Distillation Plant, Construction, Mach. & Equip.	11,000.00	1–16–45	Data not available				SD
CC-2 Plant—Revocation of Funds	−75,000.00	1–23–45					
Temperature control room (Med. Research Lab)	8,720.00	1–24–45	2–2–45	5–23–45	100	5–23–45	LS

Enlargement of concrete aprons—Whses. & Magazines.	43, 900. 00	2-13-45	5-20-45	Not available	18	8-7-45(E)	LS
Constant Temperature rooms, Bldg. 328, Addtl. Cost.	7, 835. 00	2-14-45					
Prototype Target—Addtl. Funds	20, 874. 78	2-16-45					
M77 Bomb Facility—Equipment	7, 000. 00	2-19-45	Data not available				SD
Fire Damage to WP Fill. Bldg. 501	2, 350. 00	2-20-45	Data not available				SD
Ventilating system, Impregnating Plant, Addtl. Cost.	9, 000. 00	3-2-45					
Relocate Mach. & Equip., Gage Lab.—Inspect. Division.	3, 814. 38	3-28-45	Data not available				SD
Pool Order, Machine tools for M74 Bomb Facilities.	1, 800, 000. 00	4-12-45	Data not available				SD
Refrigerated Storage Capacity, Addtl. Expansion.	56, 000. 00	6-7-45	Not available			7-21-45(E)	Not available.
Explosion Damage—Bldgs. 508, 509, Plants Area.	9, 650. 00	6-8-45	Data not available				SD
Sprinkler system—Addtl. Cost	5, 400. 00	6-15-45					
Decontamination of Ton Containers	21, 153. 00	6-21-45	Not scheduled				
Prisoner of War Camp—Reduction in Cost.	−1, 880. 79	6-22-45					
Prisoner of War Camp—Expansion—Reduction in Cost.	−6, 141. 00	6-29-45					
Huntsville Arsenal, Huntsville, Ala., Total	75, 039, 540. 38						
Original Chemical Plants	33, 973, 193. 26	To 9-22-44	7-21-41	4-1-42	100	3-30-45	FF, LS, FA, SD
Chemical Plants, Addition No. 1	7, 733, 575. 00	To 9-22-44	1-28-42	6-25-42	100	11-30-42	FF, SD
Chemical Plants, Addition No. 2	8, 200, 316. 20	To 12-14-44	5-27-42	1-1-43	100	3-30-45	FF, FA, SD
Depot Storage	17, 066, 955. 00	To 1-6-43	1-2-42	3-6-42	100	3-15-43	FF, SD
HC & CN—DM Filling Plant	4, 789, 700. 65	To 7-25-44	10-4-43	1-30-44	100	1-30-44	FF, SD
Thionyl Chloride Plant	265, 800. 00	To 2-26-43	3-15-43	4-15-43	100	4-15-43	FF
Carbonyl Iron Plant	603, 600. 00	To 9-25-43	10-28-42	3-15-43	100	6-1-43	FF

Appendix A—Status of CWS Facilities Program as of 30 June 1945—Continued

Facility and Project	Authorized Amount	Date Authorized	Construction Started	Actual or Scheduled Initial Completion	Percent Completed 6-30-45	Actual or Estimated (E) Final Completion	Type of Contract
Incendiary Bomb Filling Plants	$1, 398, 810. 00	To 12-20-44	12-28-42	4-15-43	Not available		SD
CG Manufacturing and filling	99, 530. 37	To 11-10-44	2-28-44	7-18-44	100	12-15-44	SD
Troop Facilities	527, 287. 00	To 5-16-44	6-24-42	3-26-43	100	5-1-45	LS
Prisoner of War Camp	16, 775. 00	To 11-3-44	7-14-44	8-28-44	100	8-28-44	LS
M69 Bomb, Cluster (E46) Wood containers.	10, 000. 00	1-6-45	Data not available				SD
Gas Alarm Equipment	4, 185. 00	1-13-45	Data not available				SD
WP Plant—Mach. & Equip. for unloading drums.	1, 500. 00	1-17-45	Data not available				SD
Chemical Plants, Addition No. 1—Revocation of Funds.	—250, 000. 00	1-23-45					
Pilot Plant for HC	77, 600. 00	2-2-45	Authorized but postponed				
Chlorine Plant—Caustic Fusion Pots	20, 000. 00	2-6-45	Data not available				SD
Chlorine Plant—Caustic Fusion Pots	5, 000. 00	2-19-45	Data not available				SD
Clothing Renovating Plant—Heating & Ventilating.	4, 650. 00	2-20-45	Data not available				SD
CG Plant—Engineering Services	2, 067. 75	3-13-45	Data not available				SD
Automatic Sprinkler systems	245, 400. 00	3-16-45	Not started	9-1-45	Not started	9-1-45(E)	LS
WP Plant—Mach. & Equip. for unloading drums, Addtl. Cost.	3, 000. 00	3-23-45					SD
WP Plants—Pallets, Mach. & Equip	1, 900. 00	3-23-45	Data not available				SD
Smoke Pot Filling—Mach. & Equip	4, 500. 00	3-29-45	Data not available				SD
M74 Bomb—WP Cup Filling—Mach. & Equip.	10, 000. 00	4-18-45	Data not available				SD
Storage—HC Mix	7, 500. 00	4-12-45	6-4-45	7-26-45	45	7-26-45(E)	LS
Prisoner of War Camp	17, 625. 00	4-21-45	4-25-45	6-30-45	100	6-30-45	LS
WP Shell Filling—Mach. & Equip	3, 000. 00	5-8-45	Data not available				SD

Conversion M47A2 to M47A3 Bomb Filling Line.	3,000.00	5-9-45	Data not available				SD
Original Chemical Plants—Revocation of Funds.	−2,761.16	5-15-45					
Chemical Plants, Addition No. 1—Revocation of Funds.	−37,270.50	5-15-45					
M74 Bomb Loading—Addtl Funds	51,000.00	5-16-45					SD
Launching Ramp	94,200.00	5-19-45	6-10-45	7-10-45	95	7-10-45(E)	FF
Incend. Oil Filling Plant—Mach. & Equip.	24,200.00	6-2-45	Data not available				SD
Proving Ground Const'n. Reduction of cost.	−26,398.19	6-12-45					
PWP Plant—Mach. & Equip	79,100.00	6-12-45	Data not available				SD
HC Mix—Mach. & Equip	11,000.00	6-19-45	Data not available				SD
Pine Bluff Arsenal, Pine Bluff, Ark., Total	66,652,031.60						
Incendiary Bomb Filling Plant	21,909,945.78	To 12-5-44	12-1-41	8-31-42	100	3-1-45	FF, LS, SD
Chemical Plants, Addition No. 1	21,436,225.35	To 11-23-44	3-15-42	9-15-42	100	1-30-45	FF, LS, SD
Chemical Plants, Addition No. 2	10,169,334.63	To 12-28-44	6-23-42	1-1-43	99	7-15-45(E)	FF, LS, SD
Incendiary Bomb Depot	7,027,657.00	To 11-15-44	2-8-42	2-19-42	100	3-15-45	FF, LS
HC Filling Plants	2,438,342.00	To 6-6-44	11-17-42	4-1-43	100	2-1-45	FF, SD
Miscellaneous Loading Plants	1,485,275.00	To 11-25-44	10-6-42	3-31-43	95	7-30-45(E)	FF, SD
Troop and Housing Facilities	710,754.00	To 3-23-43	10-30-42	1-1-43	100	6-6-43	FF
M50 Bomb Pump for use in Washing	5,000.00	1-10-45	Data not available				SD
Chemical Plants Addition No. 1, Revocation of funds.	−84,781.63	1-23-45					
Chlorine cells—Mach. & Equip	7,500.00	2-19-45	Data not available				SD
Concrete slabs—12 whses	2,300.00	2-19-45	Not available	Not available	100	3-1-45	LS
WP Cup Filling—Mach. & Equip	15,000.00	3-7-45	Data not available				SD
Prisoner of War Camp	6,189.00	3-20-45	4-2-45	5-15-45	100	5-15-45	PE
Chlorine Cells, Additional	3,300.00	3-21-45	Data not available				SD
Sprinkler system—expansion	8,940.00	3-31-45	2-17-45	7-15-45	71	7-15-45(E)	LS

Appendix A—Status of CWS Facilities Program as of 30 June 1945—Continued

Facility and Project	Authorized Amount	Date Authorized	Construction Started	Actual or Scheduled Initial Completion	Percent Completed 6-30-45	Actual or Estimated (E) Final Completion	Type of Contract
Chlorine Plant—Refrigeration Unit	$22,500.00	4-6-45	Data not available				SD
Reworking M50 Bomb—Mach. & Equip.	17,045.00	4-17-45	Data not available				SD
WP Plant—Settling Tank for Phossy water.	2,300.00	4-18-45	6-4-45	8-31-45	86	8-31-45(E)	PE
4.2 RCM Shell Loading	1,436,000.00	4-18-45	5-7-45	10-15-45	20	10-15-45(E)	FF
4.2 Shell Fuze—Machinery and Equipment.	9,000.00	4-25-45	Data not available				SD
I.B.F. Plant—Revocation of Funds	−11,858.01	5-15-45					
Change house, WP Area—Revocation of Funds.	−2,883.86	5-15-45					
Change house, I.B.F. Area—Revocation of Funds.	−1,452.66	5-15-45					
Prisoner of War Camp—Expansion	400.00	5-28-45	4-2-45	5-15-45	100	5-15-45	PE
Conversion of M47A2 Bomb Line to M47A3.	40,000.00	6-6-45	Data not available				SD
Rocky Mountain Arsenal, Denver, Colo., Total	39,837,061.31						
Arsenal and Land	33,983,964.28	To 12-29-44	6-2-42	1-1-43	99	7-14-45(E)	FF, LS, SD
Oil Bomb Filling Plant	920,566.54	To 9-22-44	12-30-42	7-15-43	100	4-30-45	FF, LS, SD
CG Filling Plant (Temporary)	25,000.00	11-13-43	12-4-43	2-19-44	100	2-19-44	SD
M69 Bomb Loading Plant	56,945.00	To 7-18-44	3-13-44	4-15-44	100	5-12-44	LS
M74 Bomb Loading Plant	683,220.00	To 10-31-44	9-12-44	2-28-45	100	3-1-45	FF, SD
HD Plant	1,608,000.00	8-15-44	8-15-44	4-30-45	100	4-30-45	FF
Oil Bomb Filling Plant—Revocation of Funds.	−33,178.51	1-23-45					
Chlorinated Paraffin Plant	225,000.00	2-7-45	2-17-45	5-15-45	100	5-15-45	FF

Prisoner of War Housing	52, 820. 00	2-9-45	2-12-45	3-24-45	100	3-24-45	FF
Chlorinated Paraffin Plant—Equipment.	59, 800. 00	2-9-45	2-17-45	5-15-45	100	5-15-45	FF
Remodel of 6 whses	72, 900. 00	2-12-45	2-21-45	5-15-45	100	5-15-45	FF
Addtl. Cafeteria Facilities	25, 000. 00	3-13-45	3-20-45	5-20-45	100	5-20-45	FF
M69X Bomb Loading Facilities	1, 331, 022. 00	3-17-45	3-26-45	7-20-45	85	7-20-45(E)	FF
Addtl. WP Storage	96, 200. 00	4-7-45	4-20-45	7-19-45	87	7-19-45(E)	FF
M69X Bomb Loading Facilities Additional Funds.	901, 460. 00	4-16-45					
Arsenal and Land—Revocation of Funds.	−225, 000. 00	5-15-45					
Sprinkler System—Addtl. Funds	42, 942. 00	6-21-45					
Sprinkler system—Expansion	10, 400. 00	6-28-45					
Camp Sibert, Gadsden, Ala., Total	16, 213, 000. 00						
Troop Training Facilities	16, 173, 000. 00	To 8-12-42	6-3-42	12-15-42	100	10-1-43	FF
Construction of Borden Project	5, 000. 00	10-12-43	12-22-43	1-5-44	100	5-13-44	FA
Special CWS Laboratory	35, 000. 00	11-22-43	12-15-43	4-15-44	100	7-31-44	LS
Deseret Chemical Warfare Depot, Tooele, Utah, Total	10, 946, 213. 00						
Depot and Land	10, 907, 534. 00	To 11-30-44	4-24-42	11-10-42	100	2-24-45	LS, FF
Bachelor Officers Quarters	9, 612. 00	10-15-43	11-18-43	1-31-44	100	2-15-44	UP
Trailer Project (50 Families)	23, 700. 00	11-20-44	12-4-44	2-1-45	100	2-1-45	LS
Prisoner of War Stockade	7, 552. 00	1-2-45	11-15-44	12-15-44	100	12-15-44	Not available.
Depot—Revocation of Funds	−6, 000. 00	3-12-45					
Prisoner of War Stockade—Expansion	3, 815. 00	5-15-45					

APPENDIX A—STATUS OF CWS FACILITIES PROGRAM AS OF 30 JUNE 1945—Continued

Facility and Project	Authorized Amount	Date Authorized	Construction Started	Actual or Scheduled Initial Completion	Percent Completed 6-30-45	Actual or Estimated (E) Final Completion	Type of Contract
Dugway Proving Ground, Tooele, Utah, Total	$1,692,985.14						
Proving Ground and Quarters	1,471,625.00	To 12-30-44	2-14-42	8-20-42	100	5-1-45	LS, UP
Addtl. Bldgs. and Igloos—Addtl. Cost	25,190.00	1-4-45					
New Target Area	8,000.00	4-3-45	5-3-45	6-16-45	85	8-1-45(E)	LS
Addtl. Chemistry Laboratory	60,530.00	4-30-45	6-25-45	10-1-45	5	10-1-45(E)	LS
Hangar—Gasoline Systems—Revocation of Funds.	−59.86	5-15-45					
Special Testing Facilities	10,000.00	5-21-45	5-28-45	6-4-45	100	6-4-45	LS
Two Whses. for Tech. Div. & Med. Research Center.	27,700.00	5-28-45	6-28-45	9-15-45	0	9-15-45	Not available.
Special Testing Facilities—Expansion	90,000.00	5-30-45	5-30-45	6-30-45	100	6-30-45	LS
Camp Detrick, Frederick, Md.							
Special Project	13,951,503.59	To 5-15-45	4-15-43	5-31-45	100		CPFF
Granite Peak Installation, Tooele, Utah.							
Special Project	1,474,885.00	To 9-4-44	7-10-44	1-1-45	100		CPFF
Horn Island Installation, Pascagoula, Miss.							
Special Project	454,592.90	To 5-15-45	6-28-43	10-30-44	100		CPFF
Vigo Plant, Terre Haute, Ind.							
Special Project	29,777,851.97	To 5-15-45	5-15-44	7-1-45	100		CPFF

Clothing Renovating Plants							
Columbus, Ohio							
Kansas City, Missouri	3,053,515.00	To 6-6-45	6-1-41	12-15-41	100	2-15-45	FF
New Cumberland, Penna							
Ogden, Utah							
Authorized since last report, $133,955.00.							
Note: Ogden Plant dismantled prior to completion for shipment overseas.							
Depot Storage							
Ogden, San Antonio, Memphis, New Cumberland, Atlanta, Panama, Hawaii, Philippines	12,205,906.00	6-13-40	7-15-40	5-19-41	100	5-19-41	FF
Chemical Transportation							
Chlorine Tank Cars, Freight Cars	330,140.00	3-15-42	3-15-42	6-15-42	100	10-15-42	LS
Government Owned and Contractor Operated, Total	42,233,904.65						
Niagara Falls Plant, Niagara Falls, N.Y., Total	5,711,648.68						
CC-2 Plant No. 1	2,704,413.47	To 9-22-44	2-2-41	9-4-41	100	12-31-43	FF
CC-2 Plant No. 2	3,063,000.00	To 9-22-44	10-5-42	4-1-43	100	11-15-43	FF, LS
CC-2 Plant No. 1—Revocation of Funds.	−2,834.60	5-15-45					
CC-2 Plant No. 2—Revocation of Funds.	−52,930.19	5-15-45					
Midland Plant, Midland, Mich., Total	5,233,525.90						
CC-2 Plant No. 1	2,277,771.19	To 9-22-44	2-6-41	12-16-41	100	1-15-42	FF
CC-2 Plant No. 2	2,957,793.00	To 9-22-44	9-18-42	8-15-43	100	4-15-44	LS
CC-2 Plant No. 2—Revocation of Funds.	2,038.29	5-15-45					

APPENDIX A—STATUS OF CWS FACILITIES PROGRAM AS OF 30 JUNE 1945—Continued

Facility and Project	Authorized Amount	Date Authorized	Construction Started	Actual or Scheduled Initial Completion	Percent Completed 6-30-45	Actual or Estimated (E) Final Completion	Type of Contract
St. Louis Plant, East St. Louis, Ill., Total	$6,373,311.41						
CC-2 Plant No. 1	2,518,962.06	To 9-22-44	2-1-41	12-31-41	100	1-15-42	FF
CC-2 Plant No. 2	2,837,000.00	To 9-22-44	6-23-42	3-1-43	100	12-14-43	FF
CC-2 Plant No. 1—Revocation of Funds.	−491.02	5-15-45					
CC-2 Plant No. 2—Revocation of Funds.	−176,019.34	5-15-45					
Dichloroamine-T Plant (Converted to S-330)	831,851.81	To 9-22-44	3-21-41	1-25-42	100	5-31-43	FF
Revocation of Funds	−66,005.23	5-15-45					
S-330 Plant (Converted Dichloroamine-T Plant)	437,500.00	1-28-44	2-15-44	7-15-44	100	8-11-44	FF
Interim Plant (S-330)	36,017.00	To 9-28-44	3-1-44	7-15-44	100	Not available	Not available.
Repair of Storage Tanks	4,500.00	4-26-45	Data not	available			
S-330 Plant—Revocation of Funds	−50,003.87	5-15-45					
Marshall Plant, New Martinsville, W. Va., Total	4,953,295.00						
Acetylene tetrachloride, HC and RH-195 Plant (Trichlorethylene)	5,013,295.00	To 12-13-44	7-2-43	9-1-43	100	2-20-45	FF
Revocation of Funds	−60,000.00	1-23-45					

Kanawha Plant, South Charleston, W. Va., Total	1,298,105.84						
Hexachlorethane Plant	1,277,739.00	To 9–22–44	8–30–42	2–1–43	100	10–23–43	FF
Dismantling and disposition	29,100.00	12–22–44	5–7–45	6–23–45	100	6–30–45	LS
Revocation of Funds	−1,500.00	1–23–45					
Revocation of Funds	−7,233.16	7–15–45					
Fostoria Plant, Fostoria, Ohio, Total	2,497,905.00						
Charcoal—Whetlerite Plant No. 1	1,197,905.00	To 9–16–44	4–1–41	12–23–41	100	1–10–42	FF
Charcoal—Whetlerite Plant No. 2	1,300,000.00	3–2–42	5–11–42	2–11–43	100	6–30–43	FF
Maury Plant, Columbia, Tenn.							
Charcoal—Whetlerite Plant	2,307,576.18	To 4–18–44	4–23–42	4–1–43	100	4–30–43	FF
Seattle Plant, Seattle, Wash., Total	799,691.24						
Charcoal-Whetlerite Plant and Acquisition.	796,491.24	To 9–22–44	3–30–43	12–31–43	100	2–29–44	FF, Mfg.
Sprinkler System	3,500.00	10–12–44	12–1–44	1–15–45	100	1–15–45	LS
Revocations Funds	−300.00	5–15–45					
Owl (4X) Plant, Azusa, Calif., Total	6,449,982.88						
Original Plant and Expansion	7,850,000.00	To 2–21–44	11–6–43	4–15–44	100	3–21–45	FF
Revocation of Funds	−1,400,000.00	1–23–45					
Revocation of Funds	−17.12	5–15–45					
Firelands Plant, Marion, Ohio							
Mixing and Loading Plant	726,665.00	To 9–12–44	12–4–43	4–15–44	85	9–1–45(E)	FF, LS

Appendix A—Status of CWS Facilities Program as of 30 June 1945—Continued

Facility and Project	Authorized Amount	Date Authorized	Construction Started	Actual or Scheduled Initial Completion	Percent Completed 6-30-45	Actual or Estimated (E) Final Completion	Type of Contract
Birmingham Plants, Birmingham, Ala., Total	$491,546.49						
Smoke Mix (Type C) Plant	187,837.00	To 6-26-44	12-26-43	4-15-44	100	6-30-44	FF
Smoke Pot (HC) M5 Loading Plant	303,922.00	To 12-19-44	4-17-44	7-15-44	100	9-15-44	FF
Smoke Mix Plant—Revocation of Funds	−199.98	5-15-45					
Smoke Pot Plant—Revocation of Funds	−82.53	5-15-45					
Duck River Plant, Columbia, Tenn., Total	3,317,444.25						
CG Mfg. & CO Cleaning Plant	2,851,952.00	To 8-29-44	5-6-44	12-15-44	100	1-26-45	FF
Hoists for Ton Containers	500.00	2-2-45	Data not available				
Additional Funds to complete	465,149.75	4-3-45					
Revocation of Funds	−157.50	5-15-45					
San Bernardino Loading Plant, San Bernardino, Calif., Total	1,047,228.14						
Bomb Loading Plant	193,136.00	To 12-7-44	3-1-44	4-17-44	100	Not available.	LS, SD
Mach. & Equip. for Loading Bombs	80,000.00	6-28-44	Data not available				
Tarpaulins for Storage	15,000.00	12-11-44	Data not available				
M69X Bomb Line (Pilot)	40,000.00	3-29-45	Data not available				
Conversion of M69 Bomb Line to M69X	719,100.00	4-23-45	5-18-45	8-15-45	15	8-15-45(E)	LS
Revocation of Funds	−7.86	5-15-45					

Zanesville Plant, Zanesville, Ohio, Total	743, 350.00						
Charcoal—Whetlerite Plant	733, 350.00	To 7-15-44	12-16-40	1-5-42	100	10-15-44	Mfg.
Funds to Place Plant in Standby	10, 000.00	11-10-44	Data not available				
Turlock Plant, Turlock, Calif., Total	282, 628.64						
Bomb Loading Plant (Previously reported for Chemurgic Corp.).	183, 750.00	To 12-26-44	Data not available				
Funds to Terminate Contracts Prior to Acquisition.	98, 878.64	2-2-45	Data not available				

CPFF—Cost Plus Fixed Fee
FF—Fixed Fee
LS—Lump Sum
Mfg.—Manufacturing Contract
PE—Accomplished by Post Engineer
FA—Force Account (Purchase and Hire)
SD—Service Division (Maintenance and Repair Organization at Arsenals)

Source: Report compiled semiannually by the Corps of Engineers for use of Headquarters, ASF, entitled "Facilities (including construction) Program, Chemical Warfare Service." The date of this particular report was 30 June 45.

APPENDIX B—GOVERNMENT INVESTMENT IN FACILITIES, WORLD WAR II AS OF 31 DECEMBER 1945

	ACREAGE	COST TO GOVERNMENT				
		Total	Land	Construction	Equipment & Production Machinery	Other
	408,983	$315,658,264	$6,350,341	$235,800,100	$56,328,812	$17,179,011
ARSENALS AND PLANTS						
Edgewood Arsenal Edgewood, Md.	900	37, 586, 969	70, 751	26, 592, 146	8, 583, 562	2, 340, 510
Huntsville, Arsenal Huntsville, Ala.	22, 890	58, 431, 200	1, 205, 174	43, 681, 939	8, 392, 394	5, 151, 693
Pine Bluff Arsenal Pine Bluff, Ark.	5, 170	51, 156, 748	77, 005	35, 912, 468	12, 133, 820	3, 033, 455
Rocky Mountain Arsenal Adams County, Colo.	19, 614	35, 061, 097	1, 242, 791	17, 705, 504	10, 464, 557	5, 648, 245
Bell Machine Co. Oshkosh, Wis.[a]	0	83, 516	50	83, 466	0	0
Birmingham HC Smoke Mix Plant Birmingham, Ala. Ferro Enamel Corp. Plant #2	2	148, 201	0	94, 956	13, 162	40, 083
Birmingham Smoke Pot Plant Birmingham, Ala. Ferro Enamel Corp. Plant #3	2	120, 378	0	60, 948	0	59, 430

Columbus Clothing Renovating Plant Columbus, Ohio	2	687, 143	0	356, 572	311, 570	19, 001
Duck River CWS Plant Columbia, Tenn.	11	3, 383, 130	0	2, 858, 636	467, 009	57, 485
Dugway Proving Ground Salt Lake City, Utah (Machine Repair Shop for CWS Equipment)	1	77, 600	0	24, 930	46, 170	6, 500
Fencil, William C., Co. Huntley, Ill.	48	82, 000	0	82, 000	0	0
Ferro Enamel Corp. Bedford, Ohio [a]	5	331, 417	3, 138	222, 246	106, 033	0
Firelands CWS Plant, Marion, Ohio Ferro Enamel Corp.[a]	0	362, 185	0	0	362, 185	0
Fostoria CWS Plant #1, Fostoria, Ohio National Carbon Co.	10	678, 660	6, 300	460, 768	122, 871	38, 721
Fostoria CWS Plant #2, Fostoria, Ohio National Carbon Co.	2	848, 824	1, 500	545, 100	266, 224	36, 000
Grant, Camp, Rockford, Ill. (Dismantling of Gas Masks)	0	2, 012	0	0	2, 012	0
Kanawha CWS Plant South Charleston, W. Va. Westvaco Chlorine Products Corp.	1	263, 345	0	263, 345	0	0
Kansas City CWS Plant Kansas City, Mo.	2	747, 223	0	345, 462	195, 294	206, 462

APPENDIX B—GOVERNMENT INVESTMENT IN FACILITIES, WORLD WAR II AS OF 31 DECEMBER 1945—Continued

	ACREAGE	COST TO GOVERNMENT				
		Total	Land	Construction	Equipment & Production Machinery	Other
	408,983	$315,658,264	$6,350,341	$235,800,100	$56,328,812	$17,179,011
ARSENALS AND PLANTS—Continued						
Marshall CWS Plant New Martinsville, W. Va. E. I. du Pont de Nemours & Co., Inc	84	5, 186, 279	39, 163	2, 127, 165	2, 673, 288	346, 613
McCoy, Camp, Camp McCoy, Wis. (Dismantling of Gas Masks)	0	12, 328	0	0	12, 328	0
Midland CWS Plant, Midland, Mich. Dow Chemical Co	10	5, 415, 289	0	2, 143, 526	3, 250, 385	21, 378
New Cumberland CWS Plant New Cumberland, Pa	2	341, 111	0	341, 111	0	0
Niagara Falls CWS Plant Niagara Falls, N.Y. E. I. du Pont de Nemours & Co., Inc	9	5, 028, 363	51, 930	3, 719, 810	1, 194, 606	62, 017
Owl 4X Plant, Azusa, Calif. American Chemical-Cyanamid Corp	36	4, 593, 062	0	2, 351, 113	2, 218, 159	23, 790
Rheem Manufacturing Co. Houston, Tex.[a]	0	877, 438	9, 419	546, 256	321, 763	0

San Bernardino CWS Plant San Bernardino, Calif. Day & Night Flare Corp.	594	461, 334	0	296, 900	164, 434	0
Seattle CWS Plant Seattle, Wash.	16	893, 740	231, 013	242, 171	420, 556	0
St. Louis CWS Plant, Monsanto, Ill. Monsanto Chemical Co.	22	5, 758, 613	16, 764	3, 024, 807	2, 642, 178	74, 864
Turlock CWS Plant, Turlock, Calif. Day & Night Flare Corp.	154	554, 760	7, 700	376, 658	157, 638	12, 764
Vigo CWS Plant Terre Haute, Ind.	6, 148	29, 166, 774	784, 001	27, 362, 173	1, 020, 600	0
Zanesville, CWS Plant Zanesville, Ohio.	0	203, 785	0	0	203, 785	0
DEPOTS AND WAREHOUSES						
Deseret CWS Depot Tooele, Utah.	16, 564	7, 853, 383	65, 716	7, 787, 667	0	0
Eastern CWS Depot—Training Center Edgewood, Md.	3, 872	7, 297, 130	302, 016	6, 995, 114	0	0
Gulf CWS Depot Huntsville, Ala.	16, 000	9, 717, 710	832, 000	8, 885, 710	0	0
Indianapolis CWS Depot Indianapolis, Ind.	1	0	[c]0	0	0	0
Midwest CWS Depot Pine Bluff, Ark.	9, 852	7, 172, 546	192, 981	6, 979, 565	0	0

APPENDIX B—GOVERNMENT INVESTMENT IN FACILITIES, WORLD WAR II AS OF 31 DECEMBER 1945—Continued

	ACREAGE	COST TO GOVERNMENT				
		Total	Land	Construction	Equipment & Production Machinery	Other
	408,983	$315,658,264	$6,350,341	$235,800,100	$56,328,812	$17,179,011
DEPOTS AND WAREHOUSES—Continued						
Northeast CWS Depot Modeltown, N.Y.	0	0	[d] 0	0	0	0
Chicago CWS Warehouse Chicago, Ill.	0	210, 268	0	0	210, 268	0
New York CWS Warehouse New York, N.Y.	0	321, 956	0	0	321, 956	0
BW INSTALLATIONS						
Detrick, Camp Frederick, Md.	560	12, 625, 716	70, 100	12, 555, 616	0	0
Horn Island Reservation, CWS Horn Island, Mississippi	1, 969	0	[c] 0	0	0	0
Pascagoula CWS Project Pascagoula, Miss.	4, 155	475, 000	0	475, 000	0	0

OTHERS						
Dugway Proving Ground Tooele, Utah	261, 280	3, 777, 956	[b] 0	3, 777, 956	0	0
Sibert, Camp Attalla, Ala	38, 996	17, 662, 125	1, 140, 829	16, 521, 296	0	0

[a] Defense Plant Corporation and War Department funds. The Maury CWS plant, Columbia, Tenn., built in 1942, was in standby status in 1943 and by 31 December 1945 had been declared surplus and was in the hands of the Corps of Engineers. Total cost to government was $1,330,248.

[b] 253,440 acres under permit from Interior Dept. Declared inactive 1 Oct. 1945.

[c] All under lease.

[d] Land and construction cost data included in Lake Ontario Project, Engineer Redistribution-Storage Facility.

[e] 1,969 acres public domain. Declared surplus 1 Oct. 1945.

Source: Corps of Engineers, Quarterly Inventory of War Department Owned, Sponsored and Leased Facilities, 31 December 1945, RCS AMD-1.

Bibliographical Note

Research and Development

In the chapters on research and development the author relied on records of the CWS and other branches of the armed forces, on articles, books, and interviews. For the World War I period he used records of the Bureau of Mines which trace the beginnings of chemical warfare in the United States. These documents are in the National Archives. He supplemented this with two series of monographs. The first of these was the fifty-volume Chemical Warfare Monographs prepared by chemists of the Research Division, American University Experiment Station, CWS, in 1919. These volumes are an excellent, detailed account of the work of American scientists in 1917–1918. The second series, about two hundred reports (designated by the letter H) written by commanding officers shortly after the war, give the histories of the various elements of the CWS. Both series of monographs are in the Technical Library, Army Chemical Center, Md. Some of the reports in the latter series of monographs were modified and published in chemical journals from 1919 onward.

For the period between the wars the author relied largely on reports written by chemists, physiologists, engineers, and other scientists, covering projects carried out at Edgewood Arsenal between 1920 and 1940. These reports are filed in the Technical Library where they are designated by the call letters EATR (Edgewood Arsenal Technical Report), EACD (Edgewood Arsenal Chemical Division), MD(EA)MR (Edgewood Arsenal Medical Division Memorandum Report), MRL(EA) (Edgewood Arsenal Medical Research Laboratory), MRD (Medical Research and Development Section), EAL (Edgewood Arsenal Laboratory), EAMD (Edgewood Arsenal Mechanical Division), and ETF (Edgewood Technical File). In addition the author employed articles in the *Chemical Warfare Bulletin,* a publication which, for three decades, carried articles on all phases of chemical warfare.

The author depended upon a variety of sources for the World War II period. The Technical Library has many reports under the letters DPGMR (Dugway Proving Ground Memorandum Report), TDMR (Technical Division Memorandum Report), MITMR (Massachusetts Institute of Technology Memorandum Report), and other designations that cover research, development, and testing of CWS equipment. Minutes of the Chemical Warfare Technical Committee are a mine of data on any standard item, giving reasons for the development of the item, its good and bad features, and its use. The minutes are on file in the office of the Executive Secretary of the CWTC (now the Chemical Corps Technical Committee), and in the Technical Library. Chemical Warfare Board reports, also filed in the Technical Library, supplied an evaluation of chemical items. The *Report of Activities of the Technical Division during World War II,* a paper-bound volume written by several CWS officers and issued in 1946, proved useful as a ready reference source. The score of monographs in the series, History of Research and Development of the Chemical Warfare Service in World War II (1 July 1940–31 December 1945), were useful in dealing with the major fields of smoke, mortars, and incendiaries, and with new scientific installations, such as Dugway Proving Ground, the CWS-MIT Development Laboratory, and the CWS–Columbia University Development Laboratory. These R&D monographs, available in the Historical Office, are extremely detailed in their treatment of topics. Histories of CWS installations, activities, and plants, copies of which are in the Historical Office, provided data on pilot plants and production. In the *Armed Forces Chemical Journal* from 1946 onward there appeared a number of useful articles written by members of the CWS or by contractors.

In tracing the work done by the OSRD (Office of Scientific Research and Development), the NDRC (National Defense Research Committee), and other agencies, the author used published works and unpublished technical reports. The Technical Library contains many OSRD reports on chemical warfare topics. It also has the excellent series of *Summary Technical Reports* of various NDRC divisions. These reports are in book form, but are not available to the general reader since they are classified. Members of the OSRD published a number of books after the war, including James P. Baxter's *Scientists Against Time* and Irvin Stewart's *Organizing Scientific Research for War.*

The following documents were helpful in tracing German and Japanese chemical warfare equipment: German Chemical Warfare, World War II, a mimeographed pamphlet issued by the Intelligence Division, CWS, Head-

quarters Theater Service Forces, European Theater, in 1945; German Chemical Warfare Materiel, a booklet drawn up by the Intelligence Division, Office of the Chief Chemical Warfare Officer, Headquarters European Theater of Operations; Japanese Chemical Warfare, a book prepared by the Chief Chemical Officer, USASOS, Southwest Pacific Area; Chemical Warfare Intelligence Bulletins; and the Military Intelligence Service's Tactical and Technical Trends.

In addition to records in the National Archives and other government repositories, to published and unpublished reports, articles and books, the author interviewed members of the Chemical Corps, as well as retired officers and civilians who were in the corps back in the hectic days of World War II. At the time of writing, these interviews were on file in the Chemical Corps Historical Office. Copies will be retired with permanent records of the CWS under file reference 314.7, Interviews and Correspondence File. In the same file are included letters addressed to the Chemical Corps Historical Office.

Procurement and Supply

The procurement and distribution chapters of the volume are based chiefly on official records and reports of the Chemical Warfare Service and higher echelons of the Army and on documents in such private depositories as the Chlorine Institute, New York City, and the Manufacturing Chemists Association, Washington, D.C. Much of this recorded material was supplemented by interviews and correspondence with key participants. There are two published volumes that make reference to CWS procurement and supply activities. These are Benedict Crowell's, *America's Munitions, 1917–1918* (Washington, 1919), which discusses the World War I period, and a volume entitled *The Chemical Warfare Service in World War II: A report of Accomplishments,* published in 1948, which devotes a chapter to CWS procurement and supply activities in World War II. The latter volume was prepared by the Historical Office for the Chief of the Chemical Corps and was published by the Reinhold Publishing Corporation, New York City, for the Chemical Corps Association.

In addition to Crowell's account of CWS manufacturing activities in World War I, the author made use of two unpublished histories written shortly after the close of activities by former officers. These were Lt. Col. Edwin M. Chance's, History of Edgewood Plants and Lt. Col. William McPherson's, An Historical Sketch of the Development of Edgewood

Arsenal. A copy of Chance's manuscript is in Historical Office files and a copy of McPherson's in the Technical Library at the Army Chemical Center, Md. The annual reports of the CWS for the years 1918 to 1921 contained valuable references to certain aspects of the procurement and distribution missions of the service. The reports continued to be compiled up to the fiscal year 1937, when apparently for reasons of economy they were discontinued. During World War II the Chief, CWS, resumed the practice of compiling an annual report.

For information on industrial mobilization planning and on the scanty procurement and supply activities of the peacetime period, the author used pertinent retired files of the Chemical Warfare Service; the War Department Assistant Chief of Staff, War Plans Division (WPD), G-3, and G-4; and The Adjutant General's Office. Footnote citations throughout the volume which give file numbers preceded by the abbreviation "CWS" indicate documents from the retired files of the Chemical Warfare Service. Records of the Assistant Chiefs of Staff G-3 and G-4 are indicated by the prefixes "G-3" and "G-4," respectively, those of The Adjutant General's Office by the prefix "AG." At the time this volume was written the majority of these records were in the custody of the Department of the Army. Since then, however, these records have been transferred to and are in the custody of the National Archives.

These same files, supplemented by other source material, were consulted for the emergency and war periods. The author found valuable information on the Chemical Advisory Committee to the Army-Navy Munitions Board in the files of the Chlorine Institute and the Manufacturing Chemists Association. He also searched the retired files of the Army-Navy Munitions Board, some of which were in the National Archives and others in the Pentagon. He obtained data on various aspects of CWS procurement and distribution from retired files of the Assistant Secretary of War (ASW), the Under Secretary of War (USW), the Army Service Forces (ASF), the Operations Division (OPD) of the War Department General Staff, the War Production Board (WPD), and the War Department Manpower Board (WDMB), all in the National Archives.

The author made use of appropriate monographs prepared by the Chemical Corps Historical Office and of the installation histories prepared under the supervision of that office. Copies of these monographs and histories are on file in the Chemical Corps Historical Office and in the Office of the Chief of Military History. In addition, he consulted the installation files of The Adjutant General's Kansas City Record Center. He

reviewed studies and lectures on various phases of logistics in the files of the Industrial College of the Armed Forces, those volumes in the series UNITED STATES ARMY IN WORLD WAR II that touch on logistics, unpublished monographs in the Office of the Chief of Military History, and historical accounts compiled by a few CWS World War II contractors. (It is a pity more contractors did not write a historical account.) To supplement the record of contractor activities, the author corresponded with and interviewed a number of key plant officials who had experience with the World War II program. These letters and interviews are now on file in the Chemical Corps Historical Office and copies will be retired with permanent records of the CWS under file reference 314.7, Interviews and Correspondence File.

Glossary

AAF	Army Air Forces
ABC Committee	A code designation for a Biological Warfare Committee, formed with the help of the National Academy of Sciences and the National Research Council
ABL	Allegheny Ballistics Laboratory
ABW	Antibiological Warfare Section, Hawaiian Department
AC	Hydrogen cyanide, a toxic agent; Assistant Chief
A Cml C	Army Chemical Center
ACS	American Chemical Society
ACofS	Assistant Chief of Staff
Actg	Acting
Adm O	Administrative Order
AEF	American Expeditionary Forces
AG	Adjutant General
AGD	Adjutant General's Department
AGF	Army Ground Forces
AGO	Adjutant General's Office
ALSOS Mission	Code name for an intelligence mission to Europe
ANMB	Army and Navy Munitions Board
App	Appendix
AR	Army Regulation
ASC	Army Specialist Corps; a type of charcoal used for gas masks
ASF	Army Service Forces
ASFD	Army Service Forces Depot
ASW	Assistant Secretary of War
AUS	Army of the United States
BAL	British antilewisite, a protective ointment for vesicant gas
Bd	Board
BPC	British Purchasing Commission
Br	Branch
Bu	Bureau
Bull	Bulletin
BW	Biological Warfare
C	Chief
CBI	China-Burma-India Theater of Operations
CC	CWS symbol for cyanogen chloride from June to November 1943. CK was the symbol used before and afterward.
CC–2	CWS symbol for chloroamide cloth impregnite discovered in 1924 and standard in World War II

CCmlC	Chief of the Chemical Corps, now Chief Chemical Officer (CCmlO)
CCWPD	Chicago Chemical Warfare Procurement District
CD	Civil Defense; Camp Detrick
CE	Corps of Engineers
CG	Commanding General; a CWS symbol for carbonyl chloride (phosgene), a toxic agent
Ch	Chapter
CinC	Commander in Chief
CIOS	Combined Intelligence Objectives Subcommittee, under the Combined Chiefs of Staff
Cir	Circular
CK	CWS symbol for cyanogen chloride, a toxic agent. This symbol was changed to CC in June 1943 and changed back to CK in November 1943.
CM-IN	Classified Message, incoming
Cml	Chemical
CmlC	Chemical Corps
CmlO	Chemical Officer
CMP	Controlled Materials Plan
CMR	Committee on Medical Research
CN	CWS symbol for chloroacetophenone, a tear gas
CNB	CWS symbol for a solution of CN in carbon tetrachloride and benzene, a tear gas
CNC	CWS symbol for a solution of chloroacetophenone (CN) in chloroform, a tear gas
CNS	CWS symbol for a solution of CN and chloropicrin in chloroform, a tear gas
CO	Commanding Officer
Co	Company
Cong	Congress
CofS	Chief of Staff
Contl	Control
CR, incendiary oil	CWS designation for gasoline thickened with crepe rubber, used as a filling for incendiary bombs
C SPD	Chief of the Special Projects Division, Office of the Chief of the Chemical Warfare Service
C Spec Asgmts Br	Chief of the Special Assignments Branch, Office of the Chief of the Chemical Warfare Service
CTGC	Committee on the Treatment of Gas Casualties
CWB	Chemical Warfare Board
CWC	Chemical Warfare Center, now Army Chemical Center
CWD	Chemical Warfare Depot
CWPD	Chemical Warfare Procurement District
CWS	Chemical Warfare Service
CWTC	Chemical Warfare Technical Committee
DA	Department of the Army; CWS symbol for diphenylchloroarsine
DANC	Decontaminating agent, noncorrosive, a solution of the compound RH 195 in acetylene tetrachloride
DC	CWS symbol for diphenylcyanoarsine, a vomiting gas

DCofS	Deputy Chief of Staff
Decon	Decontamination
DEF Committee	A code name for a biological warfare committee formed with the help of the National Academy of Sciences and the National Research Council
Dep	Depot
Dept	Department
DF	Disposition Form
Dir	Director
Div	Division
DM	CWS symbol for diphenylaminechloroarsine, a toxic agent, also known as adamsite
DPC	Defense Plant Corporation
DPGMR	Dugway Proving Ground Memorandum Report
DTH	Symbol for British antilewisite (dithioglyceral)
DUKW	A 2½-ton amphibious truck
EA	Edgewood Arsenal
EACD	Edgewood Arsenal Chemical Division
EAL	Edgewood Arsenal Laboratory
EAMD	Edgewood Arsenal Mechanical Division
EATR	Edgewood Arsenal Technical Report
ETF	Edgewood Technical File
Eq	Equipment
ETO	European Theater of Operations
ETOUSA	European Theater of Operations, United States Army
Exec	Executive
ExO	Executive Officer
FIAT	Field Intelligence Army, Technical
Fld Svc	Field Service
FM	Field Manual; CWS symbol for titanium tetrachloride, a smoke mixture used as a filling for smoke shells
FS	CWS symbol for a solution of sulphur trioxide in chlorosulfonic acid, a smoke mixture
FSA	Field Security Agency
Ft	Fort
FY	Fiscal year
G–1	Personnel section, division or higher unit
G–2	Intelligence section, division or higher unit
G–3	Operations and training section, division or higher unit
G–4	Supply section, division or higher unit
G agents	Nerve gases
GHQ	General Headquarters
GO	General Orders
"Goop"	A mixture of magnesium particles and asphalt used in incendiary bombs
GPO	Government Printing Office

H	CWS symbol for crude mustard gas
HA	Huntsville Arsenal
HC	CWS symbol for hexachloroethane, a smoke mixture
HCN	Hydrogen cyanide, a toxic agent
HD	Distilled mustard gas
HE	High explosive
Hist Off	United States Army Chemical Corps Historical Office
HMT	Hexamethylenetetramine, a compound effective against phosgene poisoning
HN-1, HN-2, HN-3	Nitrogen mustard gases
Hq	Headquarters
HS	A former CWS symbol for mustard gas
HV	Thickening agent composed of a 5 percent solution of methylmethacrylate in benzene
ICAF	Industrial College of the Armed Forces
ICC	Interstate Commerce Commission
IG	Inspector General
IGD	Inspector General's Department
Igloo	Concrete building of semicylindrical shape, covered with sod, used to store ammunition
IM	Isobutyl methacrylate, polymer AE, a substance used to thicken gasoline for incendiary purposes
Incl	Inclosure
Ind	Indorsement
Ind Svc	Industrial Service, Office of the Chief of the Chemical Warfare Service
Inf	Information
Insp	Inspection
Int	Intelligence
Interv	Interview
ISSCBW	Interservice Subcommittee on Biological Warfare, a British co-ordinating body
Jt	Joint
L	CWS symbol for lewisite, a toxic agent
LA, incendiary oil	CWS symbol for gasoline thickened with latex, used as a filler for incendiary bombs
LCI	Landing craft, infantry
LCM	Landing craft, mechanized
LCVP	Landing craft, vehicle and personnel
L-H	Lewisite-mustard mixtures
Lib	Library
Ltr	Letter
LVT	Landing vehicle, tracked
MC	Medical Corps
Mech Div	Mechanical Division
Mil Int Serv	Military Intelligence Service

Min	Minutes
Misc	Miscellaneous
MIT	Massachusetts Institute of Technology
MITMR	Massachusetts Institute of Technology Memorandum Report
MRD	Medical Research and Development Section
MRL	Medical Research Laboratory
MTO	Mediterranean Theater of Operations
NA	National Army; National Archives of the United States
Napalm	A mixture of aluminum naphthenate and palmitate used to thicken gasoline for incendiary purposes
NATO	North African Theater of Operations
NCO	Noncommissioned officer
NDRC	National Defense Research Committee
NP	Napalm
NRC	National Research Council
NYCWPD	New York Chemical Warfare Procurement District
OASW	Office of the Assistant Secretary of War
OC CWS	Office of the Chief of the Chemical Warfare Service
OCD	Office of Civilian Defense
OCM	Ordnance Technical Committee Minutes
OCMH	Office of the Chief of Military History
OD	Ordnance Department
Off	Office
Off O	Office Order
ONI	Office of Naval Intelligence
OPM	Office of Production Management
Ord	Ordnance
OSG	Office of The Surgeon General
OSRD	Office of Scientific Research and Development
OSS	Office of Strategic Services
OUSW	Office of the Under Secretary of War
PAPP	P-aminopropiophenone, a compound highly active in forming methemoglobin, hence a protection against cyanide
PBA	Pine Bluff Arsenal
PD	Procurement District
P.L.	Public Law
PMP	Protective Mobilization Plan
POA	Pacific Ocean Areas
POE	Port of Embarkation
PR	Procurement Regulation
Proc	Procurement
Prod	Production
Pt	Part
PT-1, PT-2, PT-3	An incendiary fuel, based mainly on "goop" and IM gasoline, and substitutes
PWP	Plasticized white phosphorus, granules of white phosphorus suspended in a matrix of rubber

"Q"	Quickie, a model of the flame thrower developed by the National Defense Research Committee
QMG	Quartermaster General
R&D	Research and Development
Readj Div	Readjustment Division, Army Service Forces
Ref	Reference
Req Div	Requirements Division, Army Service Forces
Ret	Retired
RFC	Reconstruction Finance Corporation
RMA	Rocky Mountain Arsenal
RP	Research Project
Rpt	Report
Sag paste	Antigas salve, a World War I protective ointment
Sarin	A nerve gas
Sec	Section
Ser	Series
Sess	Session
SG	Surgeon General
SGO	Surgeon General's Office
SGS	Secretary, General Staff
SIP	Special Inspection Procedure
SO	Special Order
SOS	Services of Supply
SPD	Special Projects Division, Office of the Chief of the Chemical Warfare Service
Spec Asst SW	Special Assistant to the Secretary of War
SPHINX	An overall army project concerned with testing equipment and tactics for detecting and reducing Japanese field fortifications
S.R.	Senate Resolution
SR, incendiary oil	CWS designation for gasoline thickened with smoked rubber, used for incendiary purposes
Stat	Statute(s)
Sub	Subject
Sup Div	Supply Division
Supt	Superintendent
SW	Secretary of War
SWPA	Southwest Pacific Area
SWPC	Smaller War Plants Corporation
T/A	Table of Allowances
Tabun	A nerve gas
TAG	The Adjutant General
TB	Technical Bulletin
T/BA	Table of Basic Allowances
TBCW	Technical Bulletin, Chemical Warfare
TCIR	Technical Committee Interim Report
TDMR	Technical Division Memorandum Report
Tech	Technical

Telg	Telegram
TM	Technical Manual
Tng	Training
T/O&E	Tables of Organization and Equipment
TofO	Theater of Operations
TSG	The Surgeon General
TT	Teletype
TVA	Tennessee Valley Authority
USA	United States Army
USAFFE	United States Army Forces in the Far East
USAFPOA	United States Army Forces, Pacific Ocean Areas
USASOS	United States Army Services of Supply, Southwest Pacific Area
USBWC	United States Biological Warfare Committee
USCWC	United States Chemical Warfare Committee
USFIP	United States Forces in the Philippines
USW	Under Secretary of War
VC	Veterinary Corps
VV	Mustard thickened with a 5 percent solution of methylmethacrylate in benzene (HV)
WBC	War Bureau of Consultants, a committee on biological warfare
WD	War Department
WDGS	War Department General Staff
WDSS	War Department Special Staff
WP	White phosphorus
WPB	War Production Board
WPD	War Plans Division, War Department General Staff
WRS	War Research Service, established by the President in May 1942 to consider biological warfare
XX-CC_3	Micronized CC-2, an impregnite
Z	Zanetti reports

UNITED STATES ARMY IN WORLD WAR II

The following volumes have been published or are in press:

The War Department
- *Chief of Staff: Prewar Plans and Preparations*
- *Washington Command Post: The Operations Division*
- *Strategic Planning for Coalition Warfare: 1941–1942*
- *Strategic Planning for Coalition Warfare: 1943–1944*
- *Global Logistics and Strategy: 1940–1943*
- *Global Logistics and Strategy: 1943–1945*
- *The Army and Economic Mobilization*
- *The Army and Industrial Manpower*

The Army Ground Forces
- *The Organization of Ground Combat Troops*
- *The Procurement and Training of Ground Combat Troops*

The Army Service Forces
- *The Organization and Role of the Army Services Forces*

The Western Hemisphere
- *The Framework of Hemisphere Defense*
- *Guarding the United States and Its Outputs*

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- *The Fall of the Philippines*
- *Guadalcanal: The First Offensive*
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The Supreme Command
Logistical Support of the Armies, Volume I
Logistical Support of the Armies, Volume II

The Middle East Theater
The Persian Corridor and Aid to Russia

The China-Burma-India Theater
Stilwell's Mission to China
Stilwell's Command Problems
Time Runs Out in CBI

The Technical Services
The Chemical Warfare Service: Organizing for War
The Chemical Warfare Service: From Laboratory to Field
The Chemical Warfare Service: Chemicals in Combat
The Corps of Engineers: Troops and Equipment
The Corps of Engineers: The War Against Japan
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The Ordnance Department: Planning Munitions for War
The Ordnance Department: Procurement and Supply
The Ordnance Department: On Beachhead and Battlefront
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Three Battles: Arnaville, Altuzzo, and Schmidt
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The Employment of Negro Troops
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